MAY 1959
VOL. 2 • NO. 5

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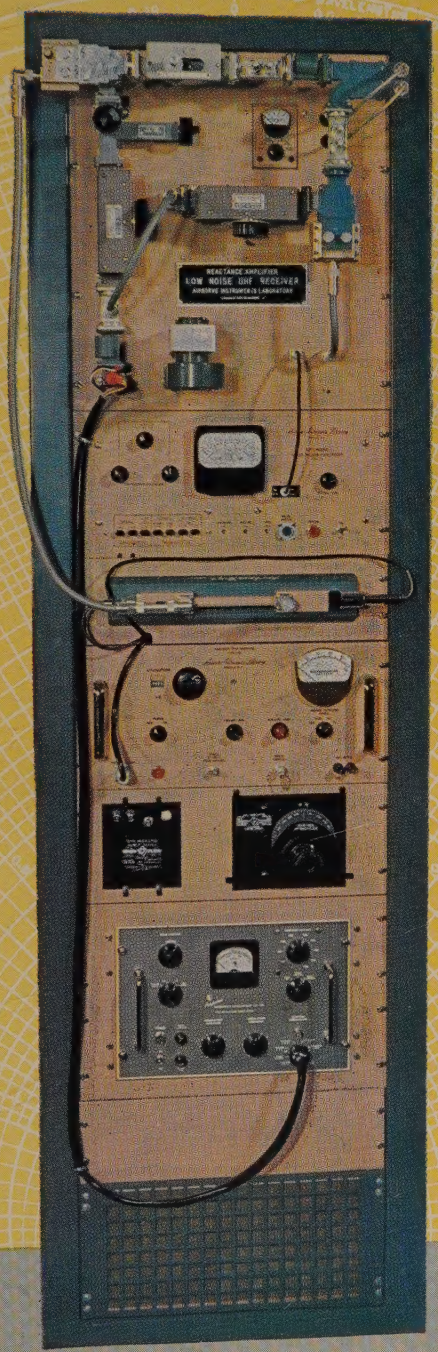
- Greene & Lombardo — 400 Mc Reactance Amplifiers
- Meronek & Van Bladel — Cigar Shaped Cavity
- Anderson — Directional Coupler Nomograms
- PGMTT Symposium Program

the microwave journal



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NEXT ISSUE — MICROWAVE COMPONENT ANALYSIS I — LOW NOISE ANTENNAS — CAVITY PARAMETER MEASUREMENTS

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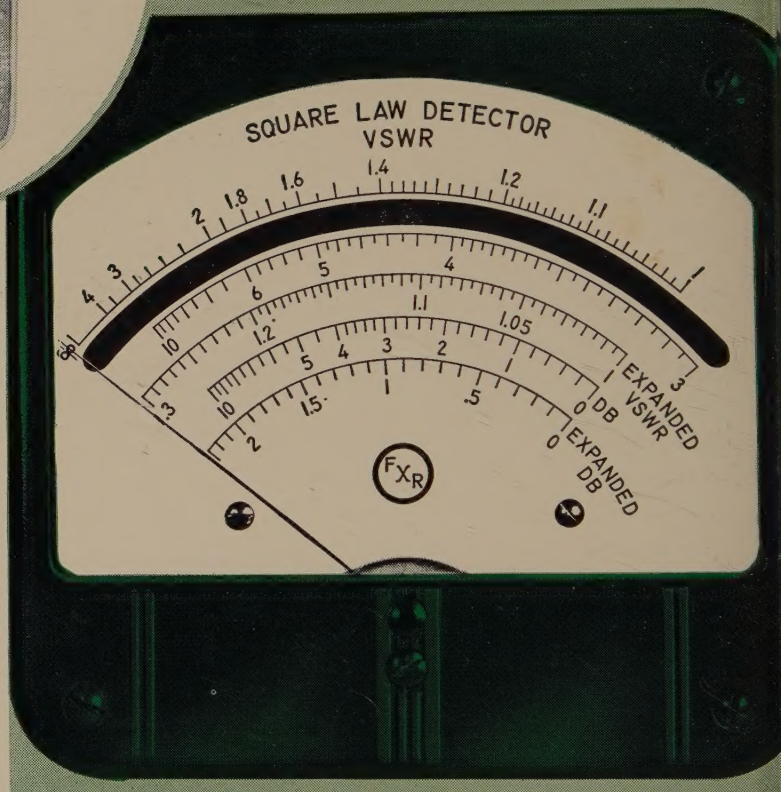

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FIRST detection of 21-cm radiation from interstellar hydrogen—1951
FIRST commercially available DC comparison radiometer — 1953
FIRST commercially available 50 kw CW power amplifiers at 960 Mc — 1955
FIRST typewritten display of extraterrestrial radio radiation — 1956
FIRST radiometer with a sensitivity of 1/400,000 — 1956
FIRST radio detection of planetary nebulae — 1957
FIRST radio detection of planet Saturn — 1957
FIRST 1000-Mc "gain-bandwidth" product masers (X-band)—1958
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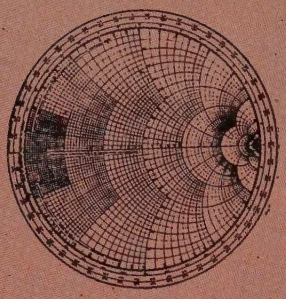

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PAUL GARRISON

COVER PICTURE

A complete 400 Mc low-noise receiving system using a reactance (parametric) amplifier as the input stage. The entire set-up is for test purposes and contains from the bottom up: a PRD Klystron power supply for the pump, a GR Unit oscillator to derive the demodulating local oscillator, an AIL Type 70A noise generator for measurement and alignment purposes, an AIL Type 130 Precision Test Receiver (30 Mc), an AIL Type 74 Automatic Noise Figure Indicator, and the experimental receiver assembly. The amplifier stage can be operated in either sum or difference frequency modes. The results are discussed in the Greene and Lombardo article on page 28.

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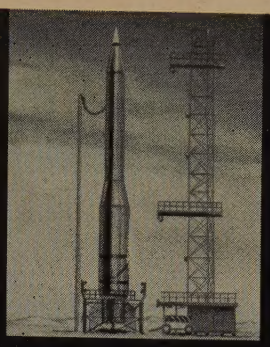

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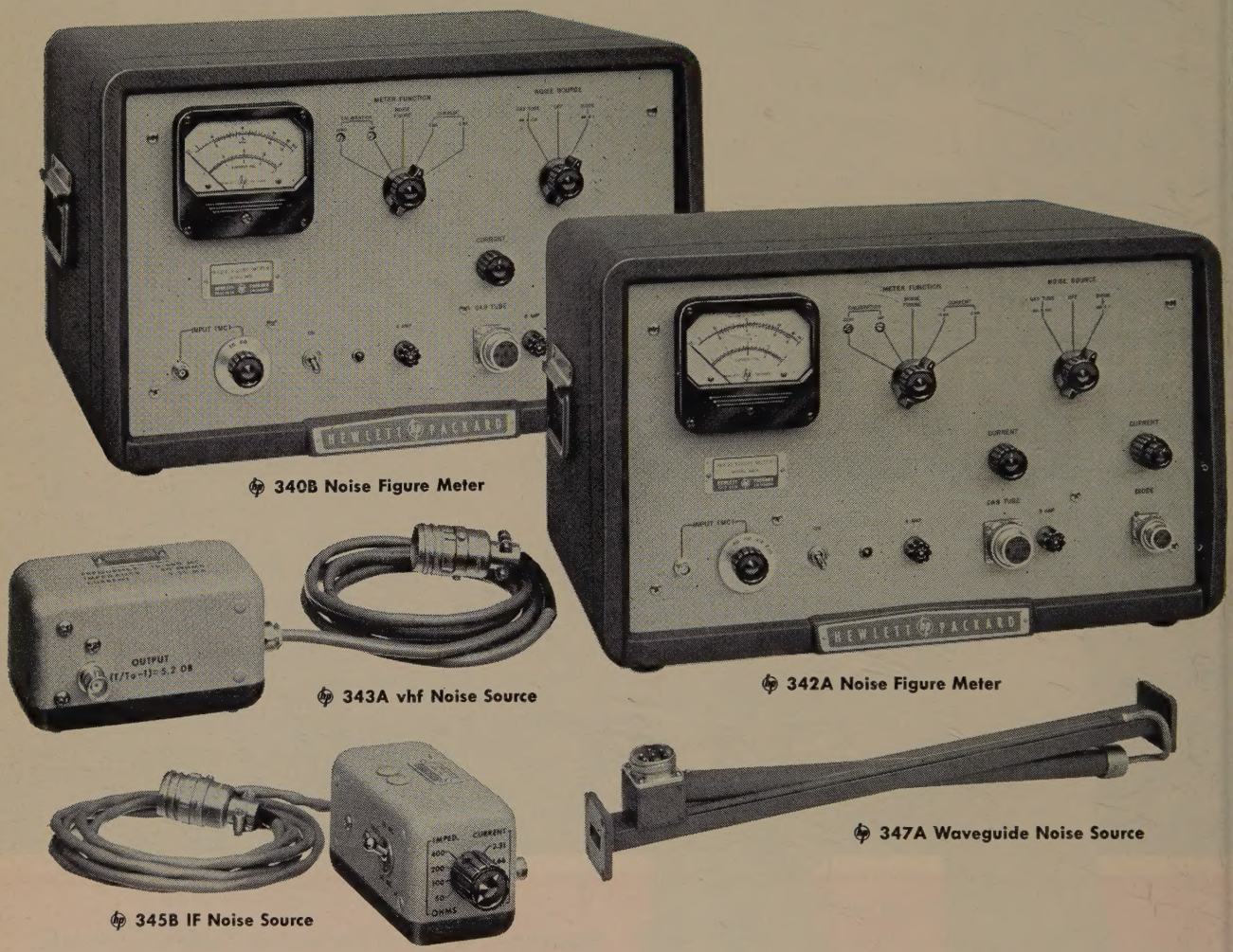

340B Noise Figure Meter

342A Noise Figure Meter

343A vhf Noise Source

347A Waveguide Noise Source

345B IF Noise Source

Now enjoy totally new speed, simplicity and accuracy in measuring and optimizing radar receivers and components, and making related measurements involving noise figure. Tasks previously requiring hours of professional engineering time now can be done in minutes by non-technical personnel. Receiver performance often can be improved over the best adjustment ever before possible. Frequently, receiver improvement equals doubling transmitter output. With accurate alignment simplified, equipment is better maintained and peak performance obtained regularly.

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- I–F, VHF AND WAVEGUIDE NOISE SOURCES

340B Noise Figure Meter. Automatically measures and continuously displays rf or IF noise figure. Supplied with 30 and 60 MC standard intermediate frequencies, *or any two intermediate frequencies between 10 and 60 MC.** Independent adjustments on gas tube and diode current controls (diode control has vernier) insure highest accuracy settings. Meter offset provision permits use of high sensitivity external meter for expanding noise figure readings.

342A Noise Figure Meter. Multi-frequency model normally supplied to accept 60, 70, 105 and 200 MC intermediate frequencies plus 30 MC. *Also available with standard IF of 30 MC plus any 4 additional frequencies from 38 to 200 MC.** Like 340B, has front panel intermediate frequency selection, extreme operating simplicity, direct readings.

343A vhf Noise Source. 10 to 600 MC, a broad-band temperature-limited diode noise source providing 5.2 db excess noise into 50 ohms. Specifically designed for use with 340B and 342A Noise Figure Meters. $75.00.

345B IF Noise Source. 30 and 60 MC, *or any two frequencies 10 to 60 MC.** Similar to 343A; front panel control selects frequencies; a second switch selects source impedances of 50, 100, 200 and 400 ohm impedances. 5.2 db excess noise. $75.00.

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Brief specifications of Models 340B and 342A are given here; for complete data on these instruments and new Noise Sources please call your Representative or write direct.

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SPECIFICATIONS

Model 340B Noise Figure Meter

Frequency Range:	Depends on noise source used.
Noise Figure Range:	3 to 30 db, indication to infinity with Waveguide Noise Source. 0 to 15 db, indication to infinity, with vhf and IF Noise Sources.
Zero Offset:	Permits low values to be read on sensitive external meter.
Accuracy:	Noise Diode Scale, ±0.5 db, 0 to 15 db. Gas Tube Scale, ±0.5 db, 10 to 25 db; ±1 db, 3 to 10 db and 25 to 30 db.
Input:	−60 to −10 dbm (noise source on). Corresponds to gain between noise source and 342A of: vhf or IF Noise Source, Approx. 50 to 100 db. Waveguide Noise Source, Approx. 40 to 90 db.
Input Frequency:	30 and 60 MC. Any two frequencies between 10 and 60 MC on special order.
Bandwidth:	1 MC minimum.
Input Impedance:	50 ohms.
Price:	$700.00 (rack mount). $715.00 (cabinet).

(Note: This instrument is available in the U.S.A. and Canada only)

Model 342A Noise Figure Meter
(same as 340B except)

Input Frequency:	30, 60, 70, 105 and 200 MC. 30 MC and any four other frequencies between 38 and 200 MC are available on special order.
Price:	$800.00 (rack mount). $815.00 (cabinet mount).

(Note: This instrument is available in the U.S.A. and Canada only)

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FROM THE EDITOR

PGMTT National Symposium #3, 4, 5, 6, 7, or 8 (?)

We would like to call attention to the Annual Symposium of the IRE Professional Group on Microwave Theory and Techniques. It will be held at Harvard University in Cambridge, Massachusetts, June 1, 2, and 3. This is without question the high point of the Microwave Year. It is hard to say what annual number we should attach to this meeting.

(1) The first PGMTT sponsored national meeting, to our knowledge was held in November of 1952 at the Western Union Auditorium in New York City. In March of the following year the first issue of the PGMTT transactions made its appearance with the symposium papers comprising the technical material.

(2) In November of 1953 the PGMTT in joint sponsorship with PGCS and PGED again held a national symposium at the Western Union Auditorium. The title was the "Microwave Radio Relay Systems Symposium."

(3) In November of 1954 a symposium on "Modern Advances in Microwave Techniques" was sponsored by the Polytechnic Institute of Brooklyn in cooperation with PGMTT. The meeting again was held in New York, but this time at the Engineering Societies Building.

(4) The next annual meeting which involved the PGMTT was the Philadelphia Symposium held at the University of Pennsylvania in February of 1956. This was co-sponsored with PGAP with the Moore School of Electrical Engineering acting as host.

(5) In April of the same year a symposium on "The Application of Ferrite Devices to Microwaves" was held at Harvard. It was sponsored by Harvard University in conjunction with the Air Force Cambridge Research Center with the PGMTT acting as a co-sponsor.

(6) At a PGMTT Administrative Committee meeting in late 1956, it was unanimously voted that the group would in the future solely sponsor and finance its own national meeting.

The annual meeting in May of 1957 was held at the Western Union Auditorium in New York. The symposium was jointly sponsored by the Long Island, New York and Northern New Jersey Chapters of the PGMTT.

(7) In May of 1958 the annual meeting was held at Stanford University, Stanford, California.

This year the meeting will be held in June as indicated above, and next year it will be held in San Diego.

This covers most of the national meetings which have been part of the annual history of the PGMTT. Not included are the efforts on behalf of URSI, the National IRE Convention, Wescon, and a few others.

The total is eight including this year's symposium. In 1956, however, there were two meetings and probably the Harvard meeting should be eliminated reducing the number to seven. Another point of view would be to count only those meetings solely sponsored by PGMTT which would leave only four meetings. It is possible you might decide to count only from May 1957 which brings us to an absolute minimum number of three.

Regardless of whether it is three or eight, the quality of the meetings have improved each year. The last meeting at Stanford was outstanding in every particular. This years meeting promises to measure up to the same high standards.

The program shown on Page 40 speaks for itself.

Anyone interested in Microwaves would be doing themselves an injustice to miss this event.

Theodore S. Saad

JOURNAL NEWS . .

Subjects featured in the June iss will be Low-Noise Antennas by C. Hansen of Hughes Aircraft C Rapid Measurement of Microwa Cavity Parameters by Richard Mo of FXR, Inc., and Graphical A alysis of Microwave Compone by George Southworth. This lat paper will appear in two parts, a continues the series on practical a plications of the Smith Chart by I Southworth which journal reade have told us are so popular a valuable.

Speaking of the June issue remin us of the journal's rapidly-approac ing first birthday. It has been a bu year, and it has had its share of ple ant surprises. Nature of readersh for example — our readers inclu top people in every phase of t thriving microwave industry. Sco — subscribers have sent for the jo nal from all quarters of the glo Growth — we are processing n subscriber applications at the rate a thousand a month, and twe thousand copies of this issue h been printed and mailed. So, d claiming any feelings of smugne we confess a rather warm impressi that our design of making the jo nal a forum and marketplace for t microwave world is shaping up.

• ● •

PAPERS

We wish to emphasize again t "the journal" is interested in rece ing papers from the industry.

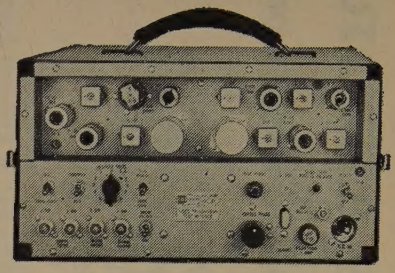
Papers can be addressed to: "the microwave journal," 159 Lind Street, Wellesley 81, Mass.

In the West Coast area, ple address all papers to: "the microwave journal," Box 11 Palo Alto, California.

Papers submitted for publicat should include: 1. Two legible c ies. 2. An abstract. 3. ORIGINA of all the figures, with capti where needed. Photographs used figures should be glossy prints. A biographical sketch of the auth 5. A glossy photograph of author, at minimum, 4" x 5", p erably, 5" x 7" or 8" x 10".

1003-C VIDEO TRANSMISSION TEST SIGNAL GENERATOR

Produces multi-frequency burst, stairstep, modulated stairstep, white window, composite sync. Variable duty cycle. Regulated power supply.



1004-B VIDEO TRANSMISSION TEST SIGNAL RECEIVER

Very rapid and accurate measurements of differential phase and differential gain characteristics of video facilities. Responds to standard stairstep test signal modulated with 3.58mc, or any differential phase or gain test signal.

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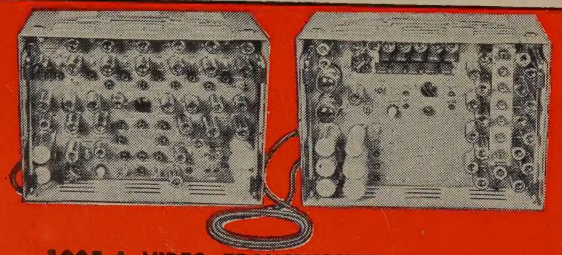
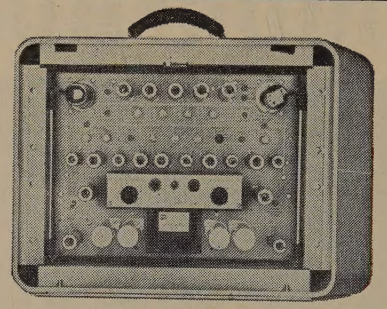


1005-A VIDEO TRANSMISSION TEST SET

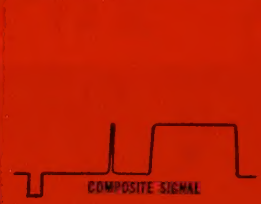
1005-A1 — Produces composite television waveforms suitable for measuring amplitude vs. frequency; differential gain vs. amplitude; dynamic linearity; differential phase vs. amplitude; high frequency transient response; low frequency transient response; low frequency phase or streaking, smears, mismatches; and other video characteristics.

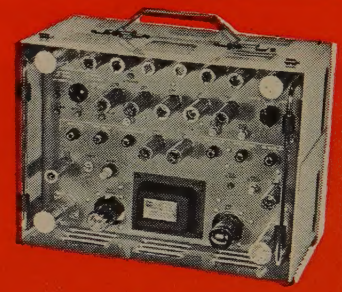
1005-A2 — Supplies composite EIA Sync, blanking, horizontal and vertical drive signals and regulated B + power for itself and 1005-A1. Features magnetic core binary counters.



1008-A VERTICAL INTERVAL KEYER

Permits test and control signals to be transmitted simultaneously with program material, between frames of TV picture. Any test signal (multiburst, stairstep, color bar, etc.) may be added to the composite program signal. Test signals are always present for checking transmission conditions without impairing picture quality. The home viewer is not aware of their presence.





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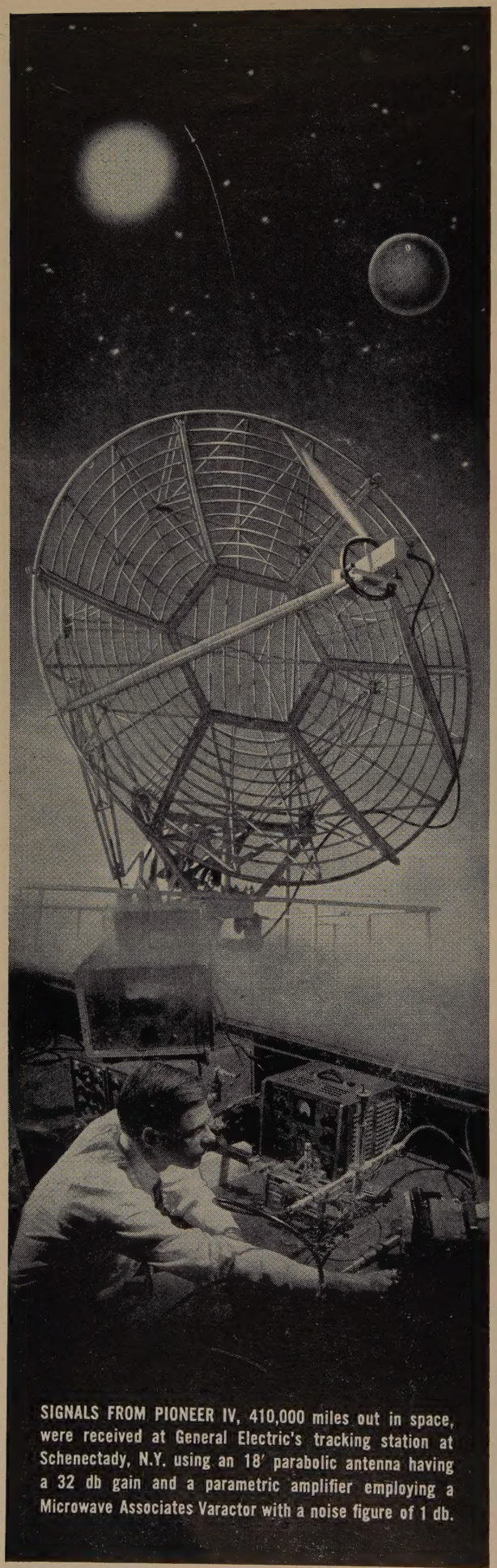

SIGNALS FROM PIONEER IV, 410,000 miles out in space, were received at General Electric's tracking station at Schenectady, N.Y. using an 18′ parabolic antenna having a 32 db gain and a parametric amplifier employing a Microwave Associates Varactor with a noise figure of 1 db.

VARACTOR PROGRESS REPORT

. . . from 410,000 miles in spac

Parametric amplifier using Microwave Associates Varactor made possible signal reception from Pioneer IV

The spectacular performance recorded at General Electric another in a series of new, immediate applications reported our customers.

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Modulators — A big field for Varactors

It's a difficult problem to impress VHF and UHF intelligence or microwave carrier. The varactor accomplishes this exceptiona well with signal gain in the side bands as opposed to low efficien techniques. Varactors are excellent high level modulators f double and single band transmitters. Signal power gain is obtain since transmitting modulators are up-convertors. Power capab ities are far superior to point-contact diodes. Further, the unifor ity of varactors facilitates carrier suppression through the use matched pairs in balanced modulators.

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Silicon is used in the MA Varactor because it has excellent pro erties at elevated temperatures, a sharper break-down character tic and, because its low saturation current allows voltage swi further into the positive region without conduction current and associated noise and losses. Germanium of course, cannot dup cate all these characteristics. Varactors approach maser perfor ance without need for refrigeration.

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Microwave Associates has recently published a brochure availa to those who feel varactors have potential in their applications. you have specific questions on applications of microwave se conductors, our Research and Development Section will be plea to help.

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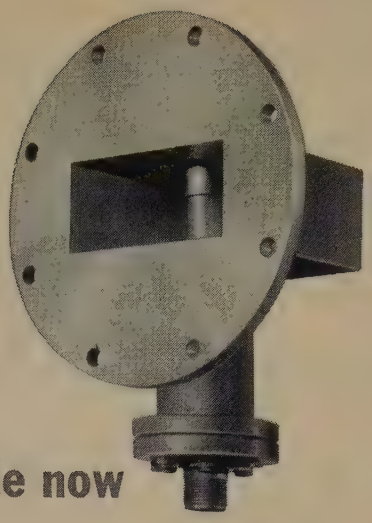

service-proved and available now

Until recently signal simulators for monitoring radar receivers or microwave relays were of two types. One was a big and heavy ampere eater with cumbersome auxiliary equipment; and the other was a sensitive though delicate instrument suitable only for the laboratory.

We call your attention now to the Litton 2000 series of miniature gas noise sources. The Litton 2000 for waveguide use is pictured above. It has a first cousin, the Litton 2007 designed for coaxial cable use. We call your attention because most tubes in this series are now in production and we suspect there are frustrated design engineers who will receive this announcement with keen interest.

Our gas noise sources may properly be called miniature. They require only inches of space, smaller, lighter auxiliary equipment, and small voltages and currents. Around 500 volts fires them; 100 milliamperes maintains them. These characteristics, plus others, have caused them to find numerous applications: for in-flight calibration and test of aircraft microwave receivers; as *automatic* watchdogs on airborne radar systems; and in other systems which require various immunities to vibration, shock, humidity, and temperature cycling.

The Litton family of miniature gas noise sources, like all Electron Tube Division products, was designed to solve specific end item functions. We have found that this philosophy contributes to consistent reliability: tubes do their jobs more efficiently, for longer periods of time, and at lower overall cost to the buyer. Other advantages also result. For example, these noise sources require *no* ageing-in and the L-2000 is replaceable in the field without changing the mount.

Specific frequency ranges in L, S, C, X and K bands are covered. If you are concerned with radar transmission, or with microwave data links of any kind, we'll gladly send you more information. Write to Litton Industries Electron Tube Division, Office M4, 960 Industrial Road, San Carlos, Calif.

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CAPABILITY THAT CAN CHANGE YOUR PLANNING

Space Year News

Astronautical Times

Fir
Edi

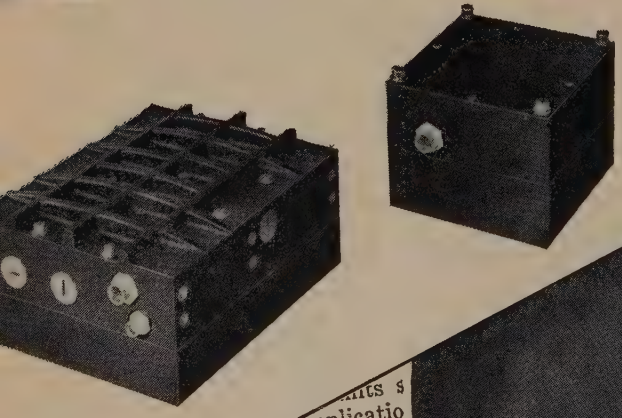
AVION RADAR BEACONS FOR ATLAS AND TITAN MISSILE

PARAMUS, N. J.—A contract for production of radar beacons to be used in the nose cone of the Atlas ICBM has been awarded to Avion Division ACF Industries, Incorporated. "This contract represents the continuation of a series

PARAMUS, NEW JERSEY—SPACE YEAR II—A contract for production of radar beacons for the U.S. Air Force Titan intercontinental ballistic missile nose cone has been awarded to the Avion Division of ACF Industries Incorporated, it was disclosed today by Richard F. Wehrlin, Avion President.

Radar beacons, Mr. Wehrlin said, are used to increase the range of ground radar while tracking the test firings of missiles, and the re-entry of nose cones, into the atmosphere.

In connection with their current space/avionic program, Avion has announced a new line of High Power C Band beacons. Send for literature.



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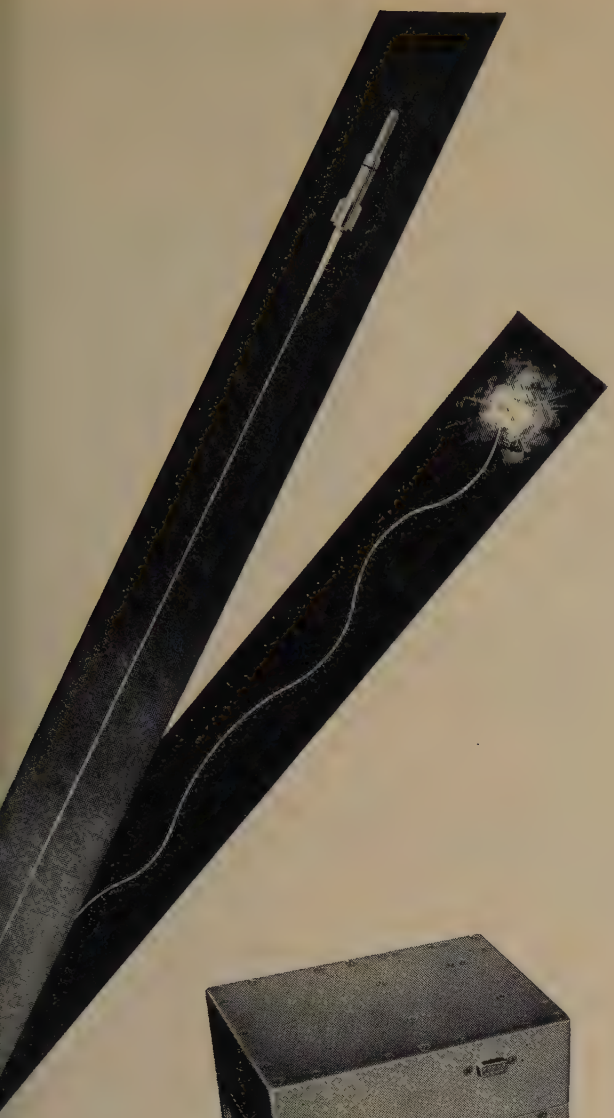

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The flight testing of second generation missiles—more versatile and powerful than their predecessors—requires a device for sure termination of any missile flight that might endanger the test range or surrounding area.

Ramo-Wooldridge engineers, under a United States Army Signal Corps contract, have successfully developed and delivered the first sub-miniature, completely transistorized radio "command destruct" receivers.

Specifically designed for missile flight safety operations, the receiver (AN/DRW-11) can actuate safety mechanisms or destruct devices. It has three command channels, each of which actuates a control relay.

The "command destruct" receiver accepts frequency modulated signals in the UHF radio command control band. It is designed to operate with closer radio frequency and command frequency channel spacing than has been used to date, thus making possible more efficient use of the available radio spectrum.

Compact and rugged, the radio receiver's modular construction permits rapid and complete accessibility to all components. One module houses the basic receiver. The second module contains the three command channels and relays. This integrated package occupies 115 cubic inches, and weighs 4 pounds. The receiver requires no pressurization and operates reliably under the adverse environmental conditions encountered in missile flight testing.

Engineers and scientists interested in being associated with some of the nation's most advanced research and development programs are invited to acquaint themselves with current opportunities at Ramo-Wooldridge. The areas of activity listed below are those in which R-W is now engaged and in which openings exist.

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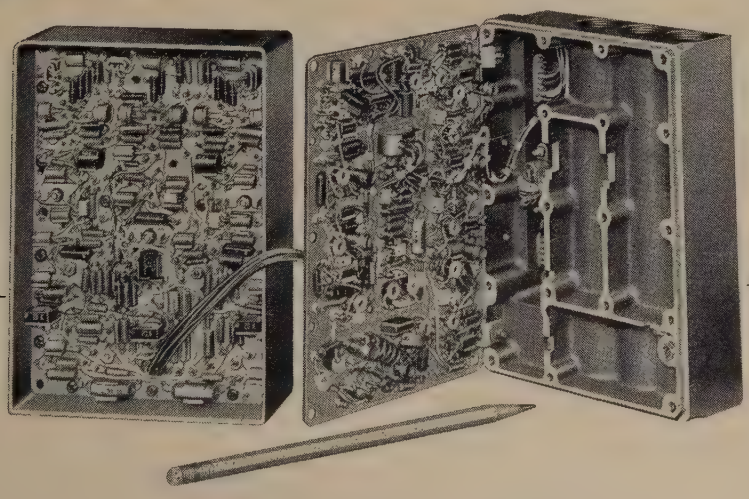

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STATE OF THE MILLIMETER WAVE ART*

Benjamin Lax and G. S. Helle

The generation of millimeter waves is one of the problems which has challenged the modern scientist. He has looked for unique solutions for creating sources of coherent radiation which would have sufficient power for use in practical systems and as a tool for fundamental research. Many of the startling and novel ideas which looked so promising have thus far not proved very fruitful. In this search for the unusual, the glamorous, and exciting breakthroughs, the obvious more straightforward approach has not received its full share of attention. Yet the few accomplishments in the millimeter field today have been the result of the extension of known techniques.

What is the problem? What can be done to solve it? The problem is as follows: There are two classes of customers who need coherent millimeter energy; first, the research engineer who would like to do original design and development of components, develop new techniques, and advance the art, and perhaps to put it to practical use in radar, communications and radiometry; second, the research physicist who desperately wants to explore physical phenomena in this no-man's-land between the conventional microwave and the infrared regions of the spectrum. What do these people need to help achieve their objectives? Above all, they need the best sources that present techniques can provide. Then they need well-engineered millimeter components and plumbing, together with equally well-engineered detectors. In essence, on a smaller scale, we are asking for a program analogous to that which existed during World War II at MIT Radiation Laboratory, Bell Telephone Laboratory, Columbia Radiation Laboratory, and related efforts throughout the country, which in a short span of a few years, extended the usefulness of the microwave spectrum in a practical way from the L-band or the 30 cm region range down to K-band or the 1 cm region. Of course it is not expected that such an explosive development of components and techniques can again or should be reproduced at the present time. However, there is a happy medium between this and the token effort which has existed in the post-war era. What we need is a well-organized and integrated effort with reasonable support which will permit the breadth, the speed which is necessary to bring about the development of sufficiently large number and variety of components on a model shop or semi-production basis, so that scientists can assemble spectrometers and test benches for fundamental investigations or for engineering design.

What have we today? There are sporadic and isolated efforts by individual researchers at universities and industrial laboratories who are working to advance the art both with and without government support. One of the outstanding examples of achievements in millimeter research under terrific odds has been the work of Gordy and his associates at Duke University who have fabricated hand-made components in order to make spectroscopic measu ments at millimeter and submillimeter wavelengths. Sligh larger, but still small-scale efforts exist at Columbia U versity, Bell Telephone Laboratories, University of Illinc University of Texas, Ohio State University, John Hopk University and a few other laboratories. These efforts ha been characterized by the fact that the components whi they have built and developed were for their own part ular needs, and although the knowledge and techniqu are disseminated, the pieces of hardware are in general r readily available to others. One notable exception is t effort of Coleman at the University of Illinois who H concentrated a fair amount of effort on component desi and has encouraged industry to actually duplicate l components and to manufacture a basic bench setup for millimeters.

One of the most difficult problems which has plagu this field has been that of obtaining sources which a sufficiently powerful, and at the same time, suitable f general use in the laboratory. To be sure, there have be magnetrons, undulators and harmodotrons which are cap ble of producing peak powers up to kilowatts down to few millimeters. Some of these are only laboratory devic and are not suitable for commercial development, with t exception of the magnetron. Another objection to the devices is the fact that they are pulsed sources rather th continuous. Pulse systems have only limited possibilit for fundamental measurements or for engineering applic tions as test instruments for component development. Un recently, the successful approach of those groups who ha actually used millimeter waves has been that of harmon generation using available commercial sources in t centimeter region. The basic element of the harmon generator as well as the detector has been the home-ma whisker crystal. Recently, tubes capable of producii energy in the milliwatt range down to 4 millimeters ha been developed, but are very difficult to obtain. The tub which look most encouraging at the present time are t Elliott VX 9206 klystron, which is capable of producii c.w. power in excess of ten watts at 8 millimeters, t Philips DX151 and the CSF carcinotron producing powe in excess of 100 milliwatts at 4 millimeters. Both Phili and CSF report similar tubes producing 2 mm radiation the milliwatt range. The greatest obstacle to the extensi use of these tubes is that they are expensive, the cost risi with the frequency, and that they are in short supply, sin they are available essentially only on a model-shop bas Let us point out that all of the above-mentioned sources a contributions from abroad.

With these higher power millimeter tubes, harmon generation techniques are now capable of producing usef amounts of one and two millimeter radiation with go potential for submillimeter generation. With the level power now available, the critical component is the whisk diode in the harmonic generator. The input power lin of the point contact diode is of the order of 200 milliwat since at this level it fails due to excessive heating, a thence "burn out" at the point-contact. This is unfortun

*The work reported in this paper was performed by Lincoln Laboratory, a center for research, operated by Massachusetts Institute of Technology with the joint support of the U.S. Army, Navy, and Air Force.

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since harmonic generation becomes more efficient at higher power levels. We must, therefore, seek new nonlinear elements capable of handling the power produced by these higher power tubes. A number of such possibilities have recently appeared in the literature. These involve the nonlinear properties of ferrimagnetic materials, ionized gases at low pressures, and variable capacitance semiconducting diodes. Thus far, generation using ferrites or garnets has been quite effective with pulsed input power. Frequency doubling from 4 to 2 millimeters has been accomplished with a conversion efficiency of the order of 17 to 20 db. The chief advantage of the ferrimagnetic materials is that they are capable of handling the power output of these c.w. tubes. However, it is not yet known what the conversion efficiency would be under continuous rather than pulsed operation. Not enough is known to evaluate the merits of the gas discharge multiplier, but fundamentally it too can handle large input powers. The device which may have the greatest potential is the variable capacitance diode. Being a junction diode, one of its virtues is that it can handle substantially higher power than the point-contact diode. Furthermore, since it is a reactive element, theoretically its efficiency can exceed that of the other types of frequency converters. The realization of effective millimeter generation with these diodes is on the horizon due to recent advances in the semiconductor art. In order to evaluate the efficiencies of the above devices, it is necessary to have some means of accurate determination of absolute power at these wavelengths from microwatts on up. Calorimeters, bolometers and waterloads are the techniques used, but again these are individually made by the researcher and are not readily available.

The detection devices which have been used are the whisker diode, the Wollaston wire bolometer, and the Golay cell. At wavelengths down to 1 millimeter, the diode seems to be as sensitive as the Golay cell; however, the response time of the former is much greater. Perha the most sensitive detector, particularly in the one mil meter region, is the bolometer. With the advent a the development of some of the improved techniques a components which we have discussed here, it now appe that millimeter masers and parametric amplifiers may h come a reality, probably at 8 and 4 millimeters initial These, of course, can become extremely sensitive low-no detectors which could rival the most sensitive devic mentioned above.

Up to now we have only discussed the convention waveguide techniques. In the millimeter and submil meter range it may be advantageous to use optical tec niques. We must use those optical techniques which ta advantage of the coherence of the radiation; i.e., Fab Perot interferometers to replace the resonant cavity, e Instrumentation of this type for this wavelength range practically nonexistent.

We have tried to make a case for creating added suppo for the development of millimeter instrumentation on larger and better organized scale than that which exi today. In particular, the production of components a relatively high powered c.w. millimeter tubes of the ty developed by the English, Dutch, and French is ab lutely essential. For a nation which is so dependent technology and advances in science, it is a great pity th we have not the foresight and where-with-all to plun more vigorously into this region of the electromagne spectrum which undoubtedly holds many secrets and s prises which will surely be revealed if the program development we described is pursued, so that basic co ponents such as tubes and other instrumentation at 4, and 1 millimeters are made accessible to physicists a engineers in universities, industry and government labo tories. The expense involved is relatively modest and benefits to be gained can indeed be great.

DR. BENJAMIN LAX was born in Hungary in 1915 and came to this coun in 1926. He received a bachelor's degree in Mechanical Engineering at Coo Union in 1941. After service in the armed forces and OCS Training, he ente MIT, receiving his Ph.D. in Physics in 1949. He has been a consultant Sylvania Electric Co., and has worked for the Geophysical Directorate of Ca bridge Research Center.

Since 1951 Dr. Lax has been with the Solid State Group at Lincoln La oratory, where he headed the ferrites group in 1953 and in 1955 he beca head of the Solid State Group. He is a member of the American Physical ciety, the Steering Committee at Lincoln Laboratory, and Sigma Xi, and is associate Editor of the Journal of Applied Physics. Dr. Lax has published m than 30 papers and has presented approximately 50 talks at various soci meetings.

GERALD S. HELLER was born in Detroit, Michigan and received his public school education in that city. He attended Wayne University in Detroit from which he received the Sc.B. in physics in 1942. He was a Staff Member of the Radiation Laboratory at MIT from 1942 to 1945, spending one year of this time as a member of the Australian Group of the Radiation Laboratory. He received the Sc.M. in applied mathematics in 1946 and Ph.D. in physics in 1948, from Brown University. He remained as Assistant Professor of physics at Brown University where he worked in theoretical acoustics. In 1954 he joined Lincoln Laboratory, MIT where he has led the ferrite application and millimeter wave programs. At present he is Leader of the Resonance Physics Group.

Creative Microwave Technology

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To meet the need for low-noise, high-resolution devices for frequency and scan conversion, Raytheon scientists and engineers have developed two new storage tubes: the single-gun QK-685 and the dual-gun QK-703. These tubes are now available in production quantities.

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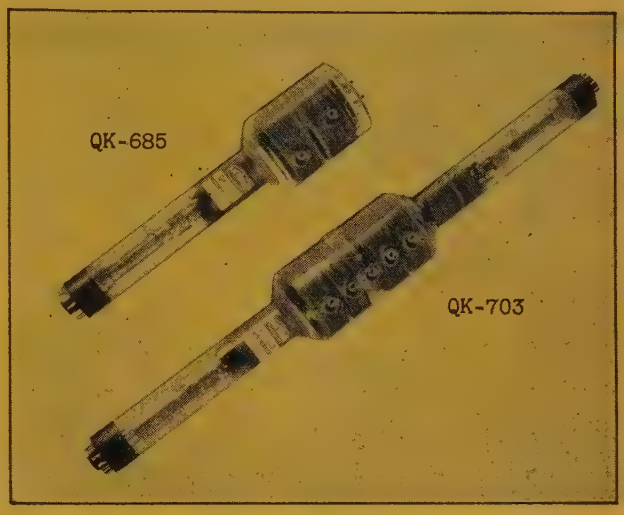
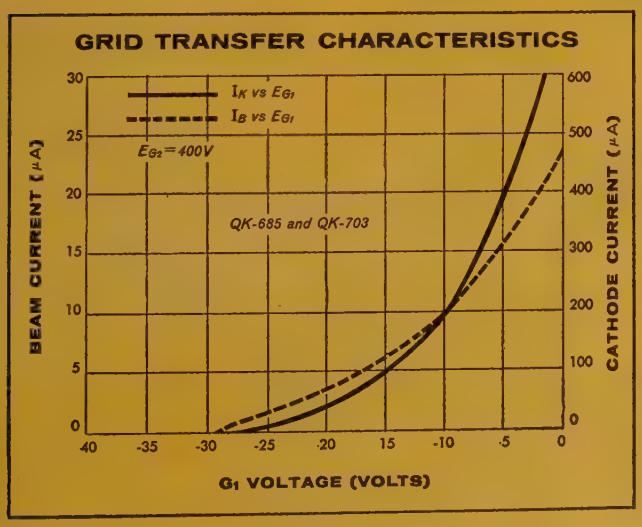
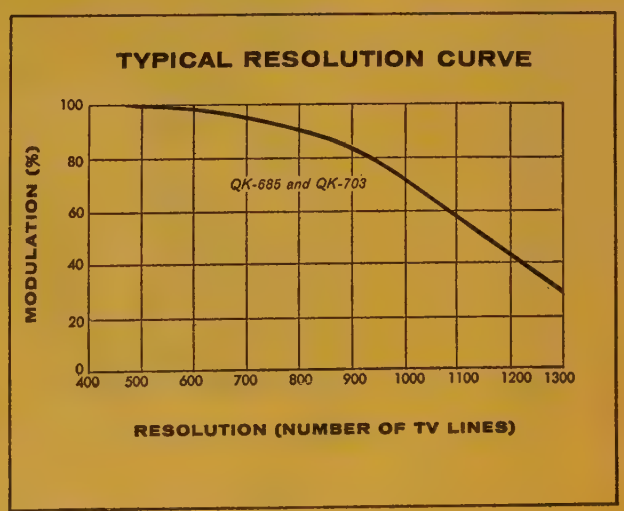


Typical Operating Characteristics

	QK-685 and QK-703
Anode Voltage	4,000 Vdc (Max.)
Resolving Power	
Magnetic Focus	1,000 Lines (Nom.)
Electrostatic Focus	700 Lines (Nom.)
Output Capacitance	QK-685—10 μμf (Nom.)
	QK-703—20 μμf (Nom.)
Maximum Deflection Angle	30°





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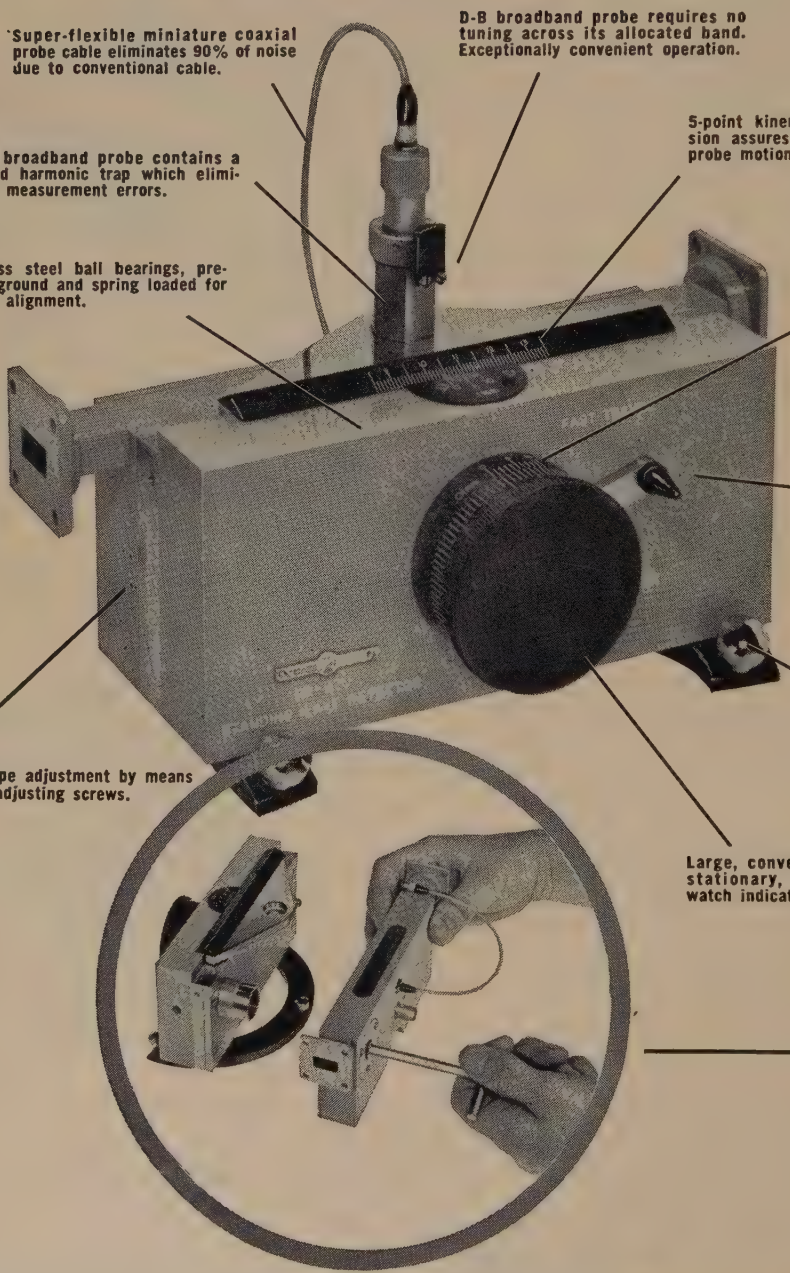
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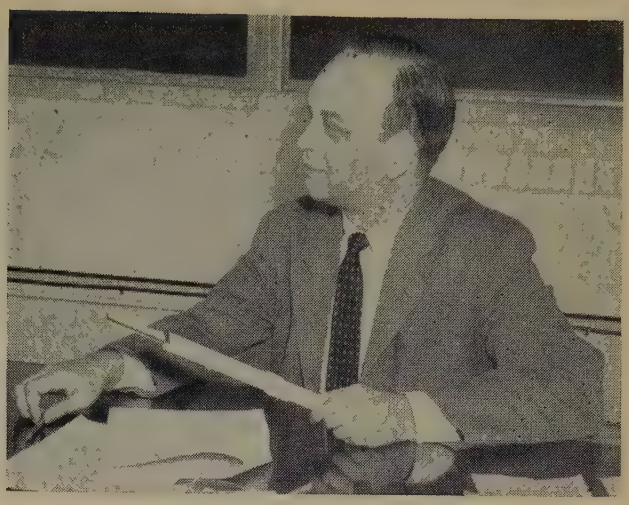
DE MORNAY BONARD I

WILBUR L. PRITCHARD

Raytheon Mfg. Co.

RADAR ENGINEER

SCIENTIST



"As the twig is bent . . ." is as apt a proverb as any to describe how Wilbur L. Pritchard was unwittingly launched on the career which now absorbs him. Born in New York City on May 31, 1923, young Pritchard might have been attracted to other fields "if it hadn't been for that man across the street who gave me an electric motor!"

With his interest sparked by the motor and what made it tick, Wilbur built himself a telegraph set. Next came a one-tube radio, and then a high-school public address system which he calls his first professional effort in electronics. About this time, he also joined his first professional society — the radio club of Townsend Harris High School in Manhattan.

"This was my first professional effort in electronics," is the way Pritchard describes the public address system which he and schoolmate Nathaniel Cohen built for use at Townsend Harris High School, Manhattan, New York, in 1938.

Young Pritchard's path toward the unknown field of microwave applications was gradually unfolding before him. By the time he was ready to enter City College of New York in 1939, his mind was made up. He would specialize in electrical engineering. Four years later he received his B.S. degree.

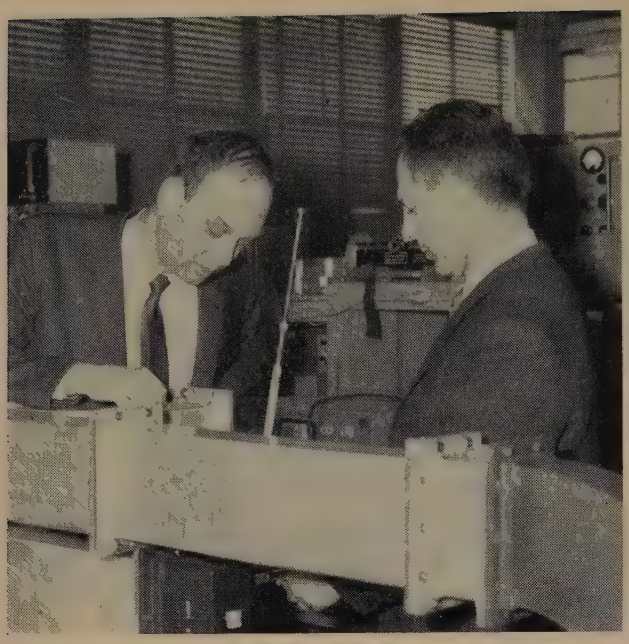
Since then, he has supplemented his technical education by taking a succession of graduate courses in electrical engineering and mathematics at MIT — all while carrying on full-time work programs. His first job (1943-1946) was with Philco in Philadelphia, where he was engaged in the development of airborne radar systems and, later, home radios and phonographs. His greatest contribution during these war years at Philco was his work on the APS-15, the first X-band bombing radar. Used in raids over Germany, it was the first radar bomb sight.

At the end of World War II, Pritchard left Philco to join Raytheon where he has been ever since, first as a group leader responsible for microwave component design of Government and commercial radar equipment in the Communications Division, Waltham. His duties included supervising five engineers in designing microwave relay systems for TRC-16 and ARC-23 equipments.

After two years at this post he was made Microwave and Antenna Section Manager of the Equipment Engineering Division and was responsible for all RF and antenna design on Raytheon's Government and commercial radars, beacons and relay systems as well as on the firm's well-known "Radarange" oven.

In 1955, Pritchard went to Raytheon's new Wayland (Mass.) Laboratory, where he now is Manager of the Surface Radar Department. Here his duties include the design of complete radar systems, ground-based and shipboard, for all applications except ordnance. Directing the activities of 275 people, he is in particular responsible for Raytheon's activities in the field of air traffic control and early warning radar.

Pritchard has achieved prominence in the fields of waveguide filters, low-noise receiver design, and long-lines effects. His paper on waveguide filters, published in 1947, has become a classic in its field. A prominent writer and



Wilbur Pritchard checks radar waveguide with Carlo P. Domenichini, his section manager at Wayland Laboratory.

speaker, he has written and published papers on a variety of other subjects which have appeared in TRANSACTIONS OF THE IRE, JOURNAL OF APPLIED PHYSICS, and other professional publications. He also finds time to be active in various professional capacities. Two years ago, he was national chairman of the IRE Professional Group on Microwave Theory and Technique, which has approximately 4,000 members. Te was also chairman of the Boston chapter of the IRE Professional Group on Microwave Theory and Technique, (PGMTT).

His public speaking has been directed at all age brackets —high school, college, business and professional groups. Once actively interested in interplanetary communication, he used to speak on the subject from time to time. However, now that the space age is upon us, and the possibility of bouncing radio waves off Venus is no longer in the realm of science fiction, he is content to leave the field of space communications to specialists who have the time to devote to it.

Concentrating on the job at hand, Pritchard has been active in the invention of many microwave devices and holds about twelve patents in this field. mostly in the categories of automatic frequency control and selective absorption.

Pritchard is currently a member of the EIA Committee on Waveguides (Coaxial Lines) and a member of the Administrative Committee of the Professional Group on Microwave Theory and Technique. He is also a member of the Society of Eta Kappa Nu and was Symposium Chairman of the 1959 PGMTT Annual Symposium at Harvard University. He holds a commercial radio telephone license, first class. He is also a Registered Professional Engineer.

As an engineer-scientist with a keen sense of the social-political-educational problems of our time, he is deeply concerned with the way in which educators and politicians are reacting to the need for more scientific education its source in the secondary schools. His editorial, "Ed cation and Science in a Mature Society," which appear in the January 1959 issue of "IRE Transactions on Mic wave Theory and Techniques," has focused attention this problem.

Pointing out that most of our political leaders have ed cational backgrounds in liberal arts, economics, law a the social sciences, Pritchard indicates that these peo "possess no more scientific knowledge than is included a one- or two-semester survey course. As a result, th never develop the slightest understanding of either t aims of scientific research or the methods of engineeri development."

He also blames educators "who, by virtue of their ov inadequate elementary scientific training, are perpetuati these standards for our next era of educators!"

The solution, Pritchard believes, is to call for a sha increase in the amount of scientific education in a ge eral curriculum. "The civilization and maturity of a f ture society will depend not on having a swarm of train robot scientists at the disposal of a non-technical dire torate, but on a blending of the goals of technology a political and social science. This will be achieved on as a result of a mutual appreciation, stemming from common educational background that provides a sou scientific understanding in addition to an awareness political and social responsibility."

Pritchard's activities are not all devoted to profession endeavor and weighty problems. An enthusiastic brid player, he has played tournament matches for years. H and his working associates have been playing this kind evening bridge at one another's houses since 1955. T game is not wholly confined to Raytheon players. Fro time to time, Pritchard and his group of champions ha beaten the Datamatic team, the team from RCA, a others.

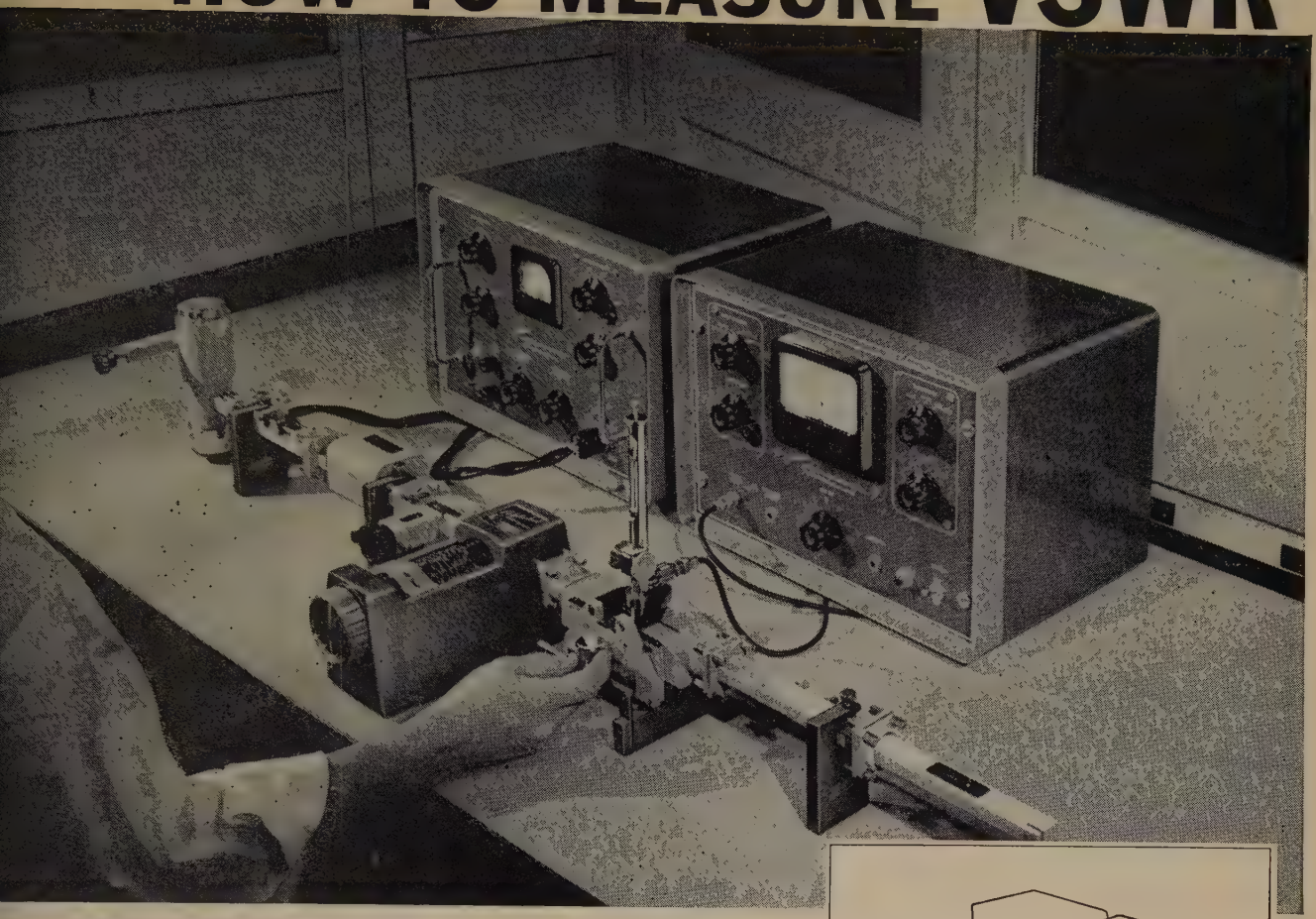
This engineer-scientist with a bent for the humanities also a camera fan. "I have a good collection from a around the United States and Europe. Color slides a black-and-white. I do my own processing, was a member the Boston Camera Club, and once won a color comp tition — a scene of pastoral France abloom in the summe time. I still follow this hobby, own a Leica and a 4x view camera."

Other activities include amateur watch repairing, wat and snow skiing, and bicycle riding. "I live about 3 miles from my job here at Wayland Laboratory and ofte between May and September when the weather is cond civé, pedal to and from work."

He leans toward amateur theatricals, too. A memb of the Sudbury Players, he has acted in a number of pla and helped to produce others. "Teahouse of the Augu Moon," given in Sudbury Town Hall last April 24 and 2 found him behind the scenes in the role of stage manag

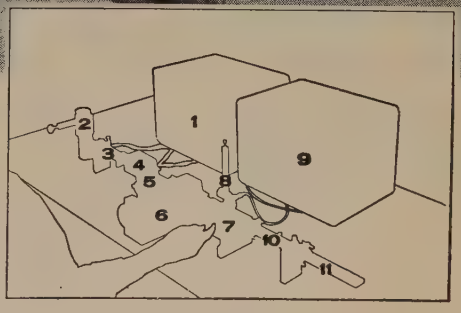
Wilbur Pritchard is married and lives on Goodm Hill Road in Sudbury, Mass. His wife, Kathleen, was bo in Canada. She has presented him with two interests n directly connected with microwaves: a boy, Hugh, 5 years, and a girl, Sarah, age 4.

HOW TO MEASURE VSWR



his microwave measurement bench is for the determination of Voltage Standing Vave Ratio using the slotted-line technique. Other systems utilizing directional ouplers or magic tees for measurement of VSWR are known, but the use of the lotted Section assures maximum accuracy.

Regardless of the technique used, accurate readings depend on the precision of ie test instruments involved. When it comes to microwave test instruments PRD roduces the widest range of the most precise equipment available anywhere in ie world.



You will notice in the measurement bench shown that there are four test components separating the klystron tube mount from the Slotted Section. These are: Slide Screw Tuner, ferrite Isolator, Level Set Attenuator, and a broadband direct eading Frequency Meter. THE USE OF THESE FOUR COMPONENTS IN THE EST LINE IS MANDATORY FOR PRECISE VSWR MEASUREMENTS!

The reason for this is clear when you consider the interrelationship between SWR, power, and frequency.

The Slide Screw Tuner is used to match the klystron output to that of the tandem st line, thereby maximizing its output and increasing its stability.

The use of the ferrite Isolator assures klystron frequency and power stability by ielding the source generator from changes in impedance further down the line. accomplishes this with negligible attenuation of the incident power. The Level et Attenuator is used to adjust the amount of power feeding the remainder of the st line.

The reaction Frequency Meter accurately monitors the output of the klystron a resonant dip on the Standing Wave Amplifier.

A Slotted Section, tuned Broadband Probe, Standing Wave Amplifier, and matched ermination complete the precision waveguide, X-band, VSWR bench. A Klystron ower Supply to provide the signal source with power and modulation and a Fixed aveguide Attenuator to simulate the unknown are also shown.

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1—809 Klystron Power Supply, catalog page F-10
2—703 Shielded Tube Mount, catalog page F-8
3—303-A Slide Screw Tuner, catalog page B-14
4—1203 Isolator, catalog page A-21
5—159-A Level Set Attenuator, catalog page A-17
6—535 Frequency Meter, catalog page D-12
7—203-D Slotted Section, catalog page B-11
8—250-A Broadband Probe, catalog page B-12
9—277-A Standing Wave Amplifier, catalog page E-7
10—UNKNOWN—represented by a 140 Fixed Waveguide Attenuator, catalog page A-11
11—116-A Waveguide Termination, catalog page A-19

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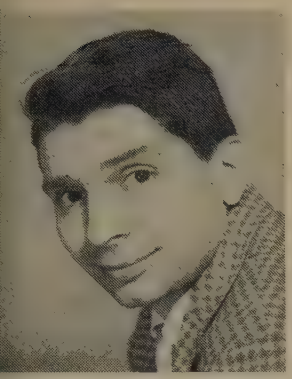
ACK C. GREENE received the B.E.E. and M.E.E. degrees from the Polytechnic nstitute of Brooklyn. From 1947 to 1948 he designed digital computers and nagnetic data-storage devices for the Teleregister Corporation. In 1948 Mr. Greene oined Airborne Instruments Laboratory, where until 1953 he performed re-earch and development work on microwave countermeasure receivers, display nd data-handling devices, and novel uses of traveling-wave tubes. From 1953 to 955 he served in the U.S. Army Signal Corps where he was assigned to the Countermeasures Division of Evans Signal Laboratory.

In 1955 Mr. Greene rejoined AIL, and is presently Section Head in the De-partment of Applied Electronics. He is currently concerned with radio astronomy eceiver design, the development of solid-state devices for receiving systems, and heoretical studies in the countermeasures and low-noise receiving systems fields.

Mr. Greene is a member of Tau Beta Pi and Eta Kappa Nu.

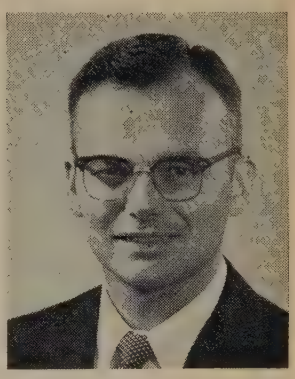


PETER P. LOMBARDO received the B.E.E. degree from the Polytechnic Institute of Brooklyn, and is presently taking graduate courses at the same college. From 1946 to 1949 he served in the U.S. Navy as an Electronic Specialist.

In June 1953, Mr. Lombardo joined Airborne Instruments Laboratory, and has been concerned with network design and the development of low-noise amplifiers. He has performed theoretical and experimental investigations on broad band amplifier coupling networks in the VHF, UHF, and microwave regions, and has also been concerned with the design of amplifier input networks used to obtain low-noise figure over broad bandwidths.

Mr. Lombardo is presently engaged in the design and development of reactance amplifiers, and microwave harmonic and subharmonic generators.

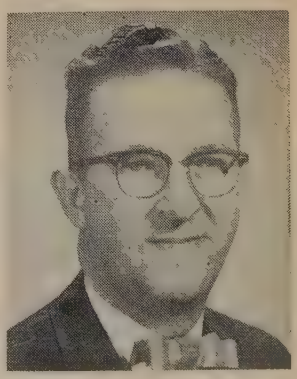
Mr. Lombardo is a member of Tau Beta Pi and Eta Kappa Nu.



DENNIS F. MERONEK was born in Custer, Wisconsin, in 1928. After a term of military service, he entered the University of Wisconsin, where he received the B.S. degree in Electrical Engineering in 1957 and the M.S. in 1958. During the academic years 1956-1957 and 1957-1958, Mr. Meronek taught electrical engineering courses at the University of Wisconsin. Since becoming affiliated with Space Technology Laboratories, Inc., in June, 1958, he has been engaged in the analysis of inertial guidance systems, as applied to ballistic missiles. He is a member of Eta Kappa Nu, Tau Beta Pi, and the IRE.

JEAN G. VAN BLADEL was born in Antwerp, Belgium in 1922. He holds a degree of Electrical Engineer from Brussels University, 1947, and obtained his Ph.D. in Electrical Engineering at the University of Wisconsin in 1950. He was head of the Radar Department, M.B.L.E. Factories, Brussels, from 1950 to 1954; Associate Professor of Electrical Engineering at Washington University from 1954 to 1956, and since 1956 has held the same position at the University of Wisconsin. He is a consultant with the M.U.R.A. Accelerator Project, and has written papers on electromagnetic field problems and electronic circuits.

Mr. Van Bladel is a Senior Member of the IRE, and a member of A.I.E.E., Sigma Xi, and Eta Kappa Nu.



MAYNARD C. WALTZ is engaged in electronic apparatus development at the Bell Telephone Laboratories, Allentown, Pennsylvania, especially with work related to silicon rectifier diodes. Mr. Waltz was graduated from Colby College in 1938 with a BA Degree in Physics, and two years later received the MA Degree in Physics from Wesleyan University. From 1940 to 1942 he taught Physics at Wesleyan, and from 1942 to 1946 worked on Microwaves in the Radiation Laboratory at the Massachusetts Institute of Technology. In 1946 he joined the Bell Telephone Laboratories. Mr. Waltz is one of the authors of "Radar Receivers," a volume in the Radiation Laboratory series and also one of the authors of "Transistor Technology" in the Bell Telephone Laboratories series. He is a member of Phi Beta Kappa, Sigma Xi, and Sigma Pi Sigma, as well as a senior member of the IRE.

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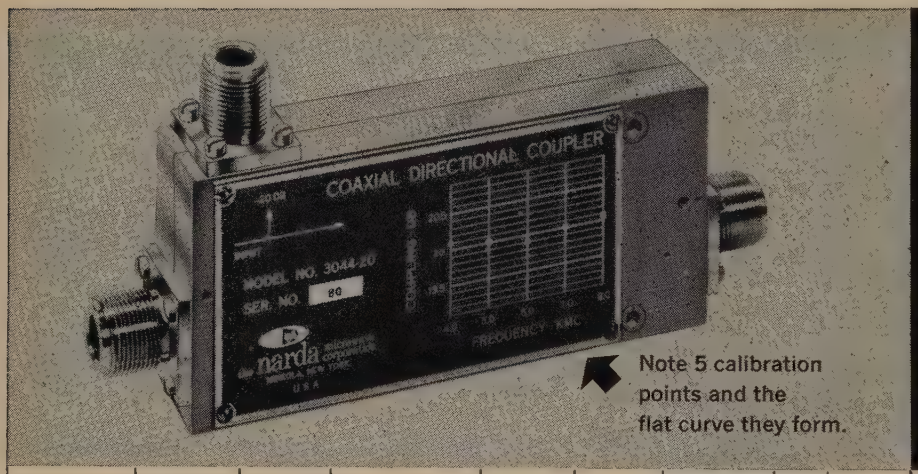

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2000-4000	20	3042-20	1.15/1.2	20	1000	200	10	
4000-8000	20	3044-20	1.2/1.25	17	1000	200	10	
7000-11,000	20	3045-20	1.25/1.3	15	1000	200	10	

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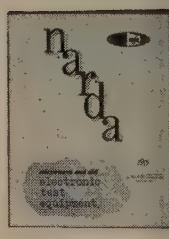

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ABSTRACT

Microwave impedance measurements are usually referred to some point in the transmission line connected through leads to the device. These measurements are of little use to the device designer who is interested in the impedance at the junction region of the device. A known impedance has been devised which permits one to compute the transformation from the measuring point to the junction region, thus overcoming the aforementioned difficulty.

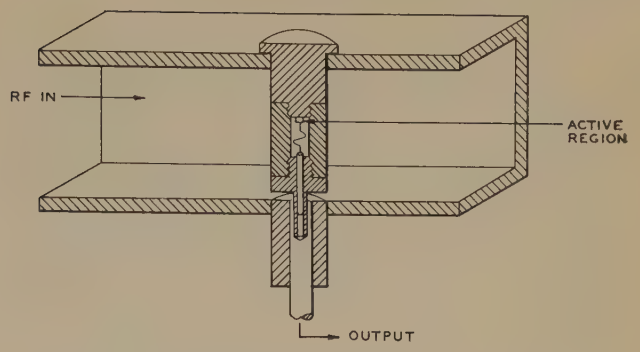

Figure 1 — Section through waveguide and diode.

A TECHNIQUE FOR THE MEASUREMENT OF MICROWAVE IMPEDANCE IN THE JUNCTION REGION OF A SEMICONDUCTOR DEVICE

M. C. WALTZ [1,2]

BELL TELEPHONE LABS., INC.

NTRODUCTION

Measurements on microwave semiconductor devices are ften meaningless from the device designers point of view nce the measurements are usually referred to some point the transmission line feeding the device and not to the tive or junction region of the device itself. The problem f referring the measurements to the active region of ie device is one of determining the usually rather mplicated transformation from the transmission line in hich the measurements are made to the interior of the vice where the active region is located. It is for the termination of this transformation that the microwave sistor to be described later in this report was developed.

ISCUSSION

In measuring the microwave impedance of a crystal rec- ier, it is customary to mount the rectifier in a wave ide as shown in section in Fig. 1. The microwave easuring energy is introduced from the left, and the ase and magnitude of the reflection coefficient is de- mined by comparing the incident and reflected waves in e guide. Since a great deal of the reflection is attributable the chuck and the case of the rectifier it is safe to say at only a part of the reflection is due to the impedance the active region of the device. This is just another y of saying that in order to relate the impedances or ad- ttances in the waveguide to the equivalent two terminal pedances or admittances at the active region, it is neces- y to determine the transformation from the line to the ive region.

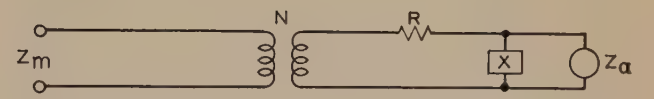

Figure 2 — Assumed equivalent circuit for waveguide-to-diode transition.

Figure 2 shows one possible lumped constant equivalent circuit of the transformation from the waveguide to the active region. In general this representation can be used at any single frequency if the losses in the transformation are small. The impedance, Z_a, is that due to the actual rectifier, N is an ideal transformer with transformation ratio, N, and X and R are the associated reactance and resistance or loss components of the transformation. The impedance as measured in the transmission line is:

$$Z_m = N\left[R + \frac{jX\,Z_a}{Z_a + jX}\right] \qquad (1)$$

so that

$$Z_a = \frac{jX(NR - Z_m)}{Z_m - N(R + jX)} \qquad (2)$$

Thus if N, R, and X are known a measurement of Z_m can be used to determine the value of Z_a.

One method of determining the parameters of the transformation is to substitute known values of impedance for Z_a and to measure Z_m. Thus if three known values of Z_a are introduced and measurements of Z_m performed, these values can be substituted in either equation 1 or equation 2, giving three simultaneous equations with the three

transformation parameters as unknowns. These equations can be solved to determine N, R, and X.

Robertson,[3] in making measurements of this type on electron tubes, has substituted for Z_a a section of coaxial line of known characteristic impedance with a moveable short circuit. Because of the much smaller size of the active region of the crystal rectifier compared to the electron tube, and thus the smaller size of the coaxial line required, it did not seem feasible to use this method for determining the transformation for the crystal rectifiers.

At first thought it appeared possible to introduce a small bead thermistor for the active region of a diode and thus make Z_a a resistor whose resistance could be altered by varying the bias and thus the temperature of the thermistor. However, if the thermistor is to be heated sufficiently to lower its resistance down to the order of 50 ohms, without heating the whole diode case, the thermistor must have reasonably long leads to furnish the necessary thermal impedance. Unfortunately these leads would also introduce a series inductance.

If a resistor could be obtained that was small in size and had leads that were negligible at the frequencies involved, then the transformer could be rather simply solved as follows:

Let

$Z_a = O$, r, and ∞ in turn, to get

$Z_m = Z_o$, Z_r and Z_∞ respectively, then

$$Z_o = NR \tag{3}$$

$$Z_r = N\left[R + \frac{jX\ r}{r + jX}\right] \tag{4}$$

$$Z_\infty = N(R + jX) \tag{5}$$

These equations can be rather easily solved to give

$$N = \frac{1}{r}\left[\frac{(Z_\infty - Z_o)\ (Z_r - Z_o)}{(Z_\infty - Z_r)}\right] \tag{6}$$

$$R = Z_o r\left[\frac{(Z_\infty - Z_r)}{(Z_\infty - Z_o)\ (Z_r - Z_o)}\right] \tag{7}$$

and

$$jX = r\left[\frac{(Z_\infty - Z_r)}{(Z_r - Z_o)}\right] \tag{8}$$

Substituting (6), (7), and (8) in (2) gives

$$Z_a = \frac{r(Z_\infty - Z_r)\ (Z_m - Z_o)}{(Z_r - Z_o)\ (Z_\infty - Z_m)} \tag{9}$$

Thus Z_a is given in terms of measurable Z's and a resistance, r, where the Z's in general are all complex. If N and R are to be made pure real in this transformation then, from equation (3), Z_o must be made real. This can be done by rotating the measurements on a Smith chart to bring the measured value of Z_o to the real axis. Then equation (3) can be rewritten as

$$\begin{aligned} R_o &= NR \\ X_o &= O \end{aligned} \tag{3}'$$

where all the terms are real.

Substituting (3)′ in (5) and calling $Z_\infty = R_\infty + jX_\infty$ we get

$$\begin{aligned} R_\infty + j\ X_\infty &= R_o + jNX \quad \text{or} \\ R_\infty &= R_o \\ X_\infty &= NX \end{aligned} \tag{5}'$$

Let us examine the characteristics to be expected from a resistor consisting of a small area contact to a resistive material. The resistance should be given by[4]

$$r = \frac{\rho}{4a} \tag{10}$$

where ρ is the resistivity and a is the radius of the contact. If a is assumed to be 10^{-3} cm, and r is 25 ohms the ρ should be 0.1 ohm cm, a readily available resistivity.

If the low frequency and microwave frequency resistances of the contact are to be equal, the current path through the resistive material should be the same in each case. These paths will be approximately the same if the skin depth is large enough at the microwave frequencies. The skin depth for non-magnetic material is given by[5]

$$T = 6.8\sqrt{\frac{\rho}{f}} \tag{11}$$

where T is in cm

ρ is in ohm cm

and f is in mc/sec.

For the 0.1 ohm cm material at 10,000 mc. the skin depth is 22×10^{-3} cm. Since almost all the resistance in a contact of this type is due to a region comparable in size with the contact diameter, this skin depth would appear to be adequate to insure that the low and high frequencies be equal. Higher resistivity material would be less troubled by this effect and lower resistivity material might be more troublesome. It would appear that a resistor of this type might be feasible.

PROCEDURE

Carbonaceous material having resistivities down to the order of 1 ohm cm are used in the fabrication of the usual composition resistors. Some hard pencil leads have a resistivity as high as .1 ohm cm. Accordingly material from these two sources[6] was used in fabricating some sample microwave resistors. The carbonaceous material was substituted for the silicon in a crystal rectifier case similar to that used in the WE IN23B silicon rectifier. The resistive material was fastened in place by the use of Dupont #4817 Silver paste, and the contact area was established with the usual tungsten "S" spring. Controlling the deflection of the spring controlled the contact area and thus the resistance. A series of resistors were made having resistances from 18 to 300 ohms. In addition a short circuit and an open circuit were made in the same cases.

Measurements were performed on these resistors by placing them in a mixer mount of the type used for measuring crystal rectifiers. All the measurements were made at 9,000 mc/sec. The measurement consisted of a determination of the standing wave voltage ratio in the input transmission line and the determination of the voltage minimum with respect to an arbitrary point in the line.

A plot of this data on a Smith chart is shown in Figure It is not difficult to determine from a plot of this type whether the resistors are resistive or not. First rotate the plot so Z_o is real to satisfy the assumptions of equation (3)′. Then if the devices are pure resistive, the values Z_o, Z_∞ and Z_r when substituted into equations (6), (7) and (8) should lead to real values for N and R and imaginary values for jX.

Let

$$\begin{aligned} Z_o &= R_o + jX_o \\ Z_r &= R_r + jX_r \\ Z_\infty &= R_\infty + jX_\infty \end{aligned}$$

substitute these in equation (8) and equate the imagina

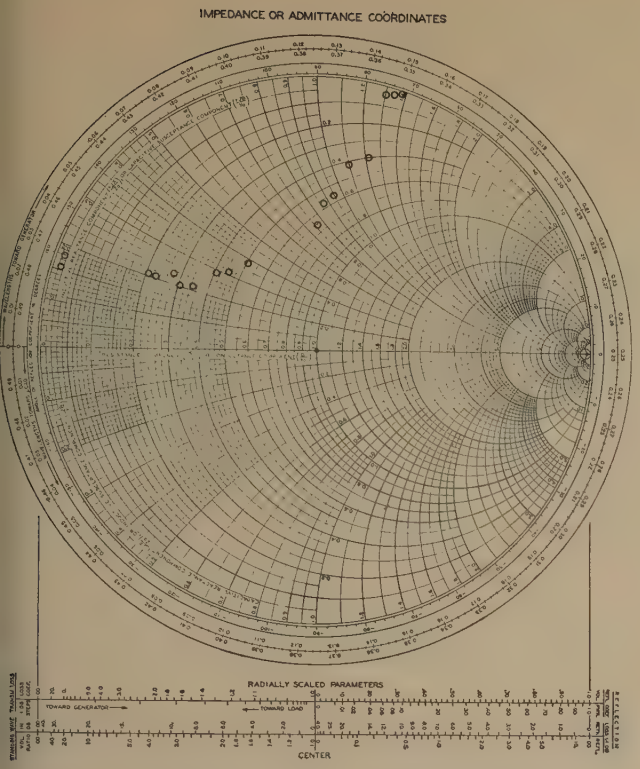

Figure 3 — Observed impedances of microwave resistors.

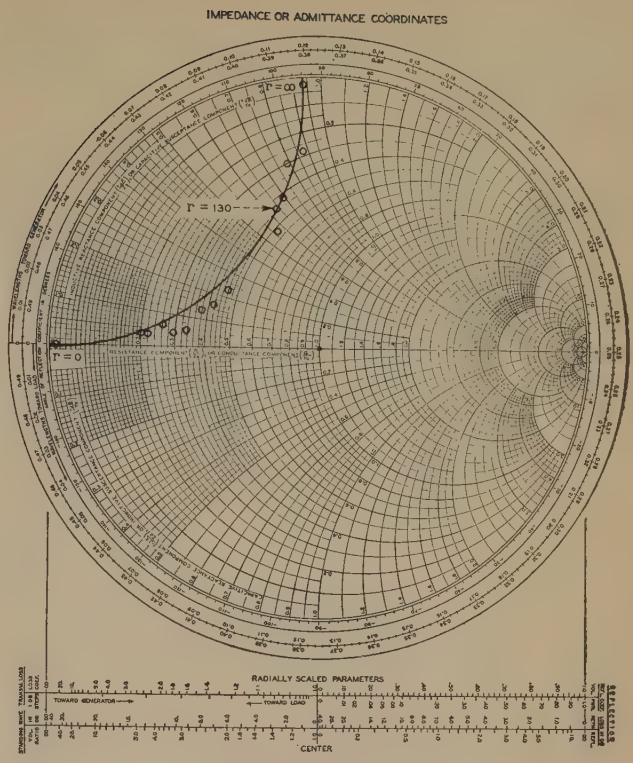

Figure 4 — Observed impedances of resistors compared to computed values.

omponents. This leads to $X_r^2 - X_r(X_o + X_\infty) + X_oX_\infty - (R_r - R_o)(R_r - R_\infty) = O$. Making use of equation 5)′ we get

$$X_r = \frac{X_\infty}{2} \pm \sqrt{\frac{(X_\infty)}{(2)} - (R_r - R_o)^2} \qquad (12)$$

his gives the relationship between the measured values of $_r$ and R_r if the measured devices are pure resistive. A lot of equation (12) on a Smith chart is drawn in Figure along with the measured data of Figure 3 after rotating ie data to make $X_o = O$. It can be seen that the fit is ot unreasonable between the measured data and the calulated curve. If it is assumed, based on previous reason-g concerning the effect of skin depth, that the microwave id low frequency resistances are equal for the point = 130, the transformation can be computed using equaons (6), (7) and (8). The following results are obined:

$$N = \frac{1}{94} = .0106$$
$$R = 1.0 \text{ ohms}$$
$$jX = j88 \text{ ohms} \qquad (13)$$

hese values can be substituted into equation (2) to perit an evaluation of Z_a when Z is measured. This gives

$$_a = \frac{82(R_m - .0106) - j88[(R_m - .0106)^2 - X_m(.93 - X_m)]}{(R_m - .0106)^2 + (.93 - X_m)^2} \qquad (14)$$

Table 1 shows the result of using equation (14) to dermine the impedances of the various resistors measured Figure 4. As can be seen from an examination of Table there are some disagreements between the direct current sistances and the microwave frequency resistances but the rrelation is reasonably good. Since with one exception all the high frequency resistances are low, it is possible that the choice of another resistor to determine the transformation would give a closer check.

It would be well to mention here that it is possible to analyze the measured results by still another method. [7, 8] This method is described in more detail in the references. It can be shown that, if the losses in a transformation are small, a series of resistors measured through the transformation will fall on a straight line when plotted on a Deschamps projection. In this projection the points are plotted on a regular Smith chart but the square of the VSWR rather than the VSWR itself is plotted radially. A plot of this type using the same data of Figure 3 is shown in Figure 5. The data leads to a reasonable fit to a straight line. In this method of analysis the relative values of impedance are read directly by the use of a "hyperbolic protractor." The values of the real part of the impedance of

TABLE I

r(DC)	Z_a Computed (9,000 mc) ohms	R_a (Deschamps)
18	18 + j0	21
21	21 + j0	23
41	26 + j0	26
35	27 − j4	29
40	30 − j5	30
45	39 − j4	41
50	45 − j4	48
63	54 − j5	56
140	110 − j9	120
130	130 + j0 ←	130 ←
200	170 + j0	150
250	230 + j23	210
300	290 − j24	270

← Used to determine transformation.

the resistors read by this method are shown in the third column of Table 1. As can be seen, the values check reasonably well with the values obtained by the previous transformation.

It would be well to discuss the errors of measurement for this set of data. These preliminary measurements were made using a sensitive galvanometer as the indicator of the VSWR. A slight shift in the zero of the instrument made a large error in the values of the VSWR. The smallest distance that could be estimated on the slotted section was 0.01 cm or 0.003 wavelengths.

It was also noted at this time that the position of the minimum when the zero ohm resistor and twenty ohm resistor were in place in the waveguide depended on the way in which the resistor was rotated in the mount. This was presumably due to the lack of rotational symmetry of the resistor, notably in the "S" bend of the spring contact. Since this effect shows up only when the resistance is small, it must be due to magnetic coupling between the spring and the waveguide. Accordingly these resistors were disassembled and the orientation of the spring determined and marked on the outside of the case so that they could be inserted reproducibly. To improve the measuring accuracy, a double detection means was obtained to measure the VSWR.

Another innovation can now be introduced to simplify the interpretation of the results. Suppose we add a stub tuner or equivalent to the waveguide plumbing associated with the diode holder. This can be thought of as adding a variable transformer, a variable reactance and some additional loss as shown in Figure 6(a). If the losses are assumed to be small, the impedances on both sides of the second ideal transformer may be reflected into a single impedance consisting of one series resistance to represent the total loss and one shunt reactance. Now the combination of the two ideal transformers, and a proper adjustment of the variable reactance can lead to a single transformer and elimination of the shunt reactance as shown in Figure 6(b). Figure 6(a) and 6(b) are equivalent if

$$R = r + \frac{R_v}{n}$$

$$X = \frac{X_v}{n}$$

and

$$N = nn_v \qquad (15)$$

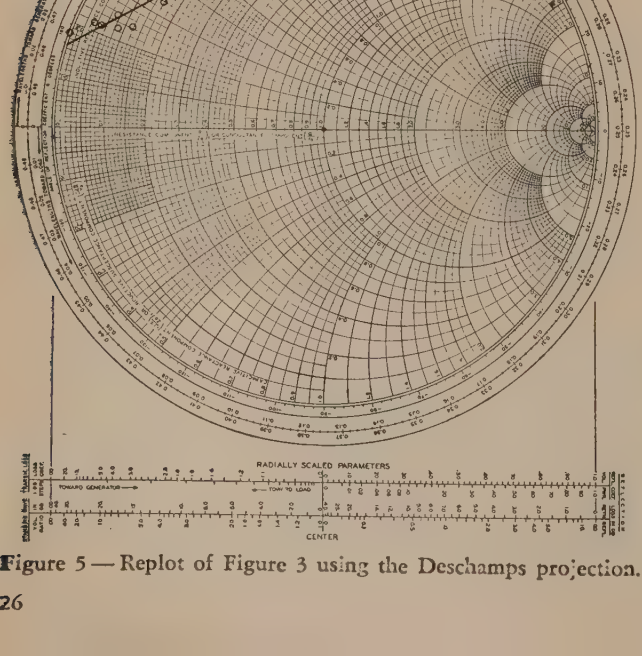

Figure 5 — Replot of Figure 3 using the Deschamps projection.

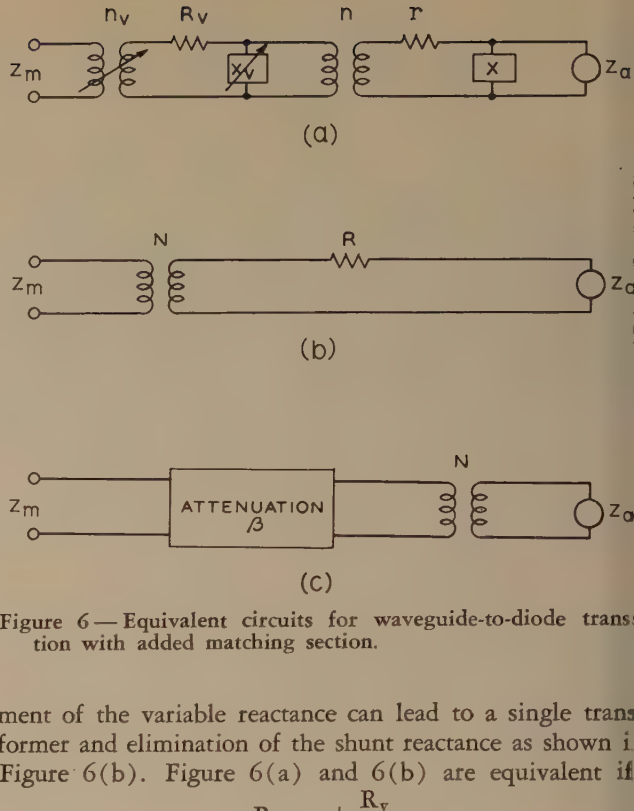

Figure 6 — Equivalent circuits for waveguide-to-diode transition with added matching section.

The conditions expressed by equation (15) are satisfied from the measurement standpoint when the position of the minimum of the standing wave in the measuring line is shifted exactly one-quarter wavelength as a short and open are substituted for Z_a. The transformation N is then determined by placing a known resistance in the circuit and measuring Z_m. The value of Z_m should be real and

$$N = R_m/R_a \qquad (16)$$

Using the technique described above, another group of resistors was measured and plotted. The results are shown in Figure 7. In this case, the deviation of the measured value of the resistor from a pure resistance is considered to be a significant effect. The lower resistance resistors were all made from material of the same resistivity and the higher resistance units were made from a higher resistivity material. The variation of resistance was due to a differing area of contact in the resistors. If the resistive material has a surface film, the overall impedance of the device could be represented by an equivalent circuit as shown in Figure 8. Here R is the spreading resistance due to the bulk of the material and R_s and C_s are the resistance and capacitance due to the surface film. If the film is assumed to have a constant thickness, both R_s and the reactance due to C_s decrease inversely with the square of the contact radius, while the bulk resistance only decreases inversely as the contact radius. Thus larger contact radii resistors have essentially only the resistance due to the bulk material while the smaller contact radii resistors have a capacitive and additional resistive component due to the surface.

An examination of Figure 7 will show that it is not strictly proper to assume that all the losses in the trans-

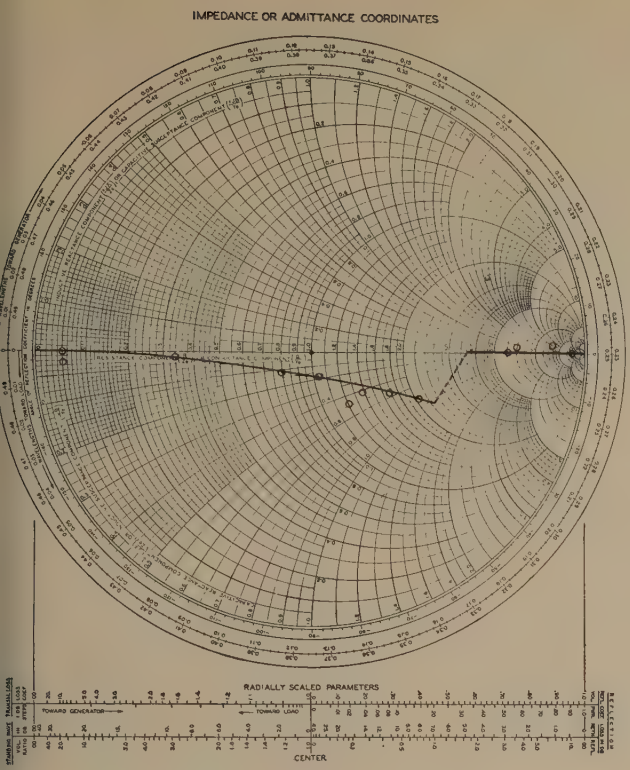

Figure 7 — Observed impedances of resistors.

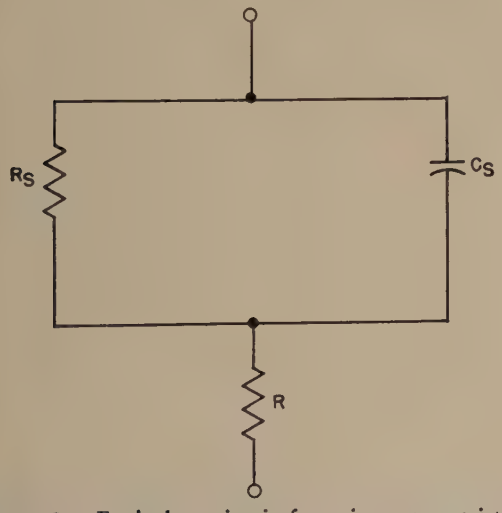

Figure 8 — Equivalent circuit for microwave resistor.

ormation could be represented by a series resistance. It ould be more accurate to introduce the losses in the ansformation by an attenuator as shown in Figure 6(c). he value of β can be determined directly by a measure- ent of the VSWR with an open or short circuit at Z_a. t can be shown that:

$$\beta^2 = \frac{\rho_o - 1}{\rho_o + 1} \qquad (17)$$

here β is ratio of the output to input voltage of the tenuator and ρ_o is the VSWR with the short or open in lace. Now if a VSWR of value ρ_m is measured on the enerator side of the attenuator, then the VSWR must be on the load side, where

$$\frac{(\rho + 1)}{(\rho - 1)} = \beta^2 \frac{(\rho_m + 1)}{(\rho_m - 1)} \qquad (18)$$

CONCLUSION

By using a microwave resistor, an open and a short, it is possible to adjust the measuring equipment and calibrate it so that the two terminal impedances of microwave components can be read directly from a Smith chart. It would appear that this would be a very useful technique in gaining understanding of the operation of microwave components such as crystal rectifiers, transistors and vacuum tubes. An appendix outlines the step by step procedure to be followed for making and using these resistors.

APPENDIX

Experimental procedure for microwave "resistor" use.

1. Assemble resistors, including an open and short, in the same case in which the device to be measured will be assembled.

2. Insert the open and short alternately in an adjustable measuring mount and locate the positions of the minimum while adjusting the transformer. Adjust until the minima for the open and short are one-quarter wavelength apart.

3. Insert the short circuit and locate the position of the minimum as the reference point to which subsequent measurements will be referred. Determine the VSWR and use this information to determine β^2 from equation (17).

4. Measure the resistors in the same mount, correct for loss using equation (18), and plot on Smith chart using the reference point in step 3 as the zero.

5. If the resistors fall reasonably close to the zero reactance line, determine N in equation (16), assuming R_a can be determined by reading the direct current or low frequency resistance of the resistor. Now 1/N can be considered as the effective characteristic impedance at the center of the Smith chart.

6. Measure the unknown, correct for loss and plot on the Smith chart.

7. Read from the Smith chart the two terminal impedance of the unknown.

REFERENCES

[1] Bell Telephone Labs, Inc., Allentown, Pa.

[2] This work was done on Signal Corps contract DA-36-039-sc-5589.

[3] Robertson, S. D., "Electronic Admittances of Parallel-Plane Electron Tubes at 4000 Megacycles." BSTJ, V28, No. 4, Oct. 1949, p. 619.

[4] Torrey, H. C., and Whitmer, C. A. "Crystal Rectifiers," McGraw-Hill, 1948, p. 428.

[5] "Reference Data for Radio Engineers," 3rd ed. 1949, Federal Telephone and Radio Corp., p. 87.

[6] 10 ohm, 2 watt, KS-13492 composition resistor for 1 ohm cm., and Koh-I-Noor 2200/6H graphite leads for the 0.1 ohm cm.

[7] G. A. Deschamps, "Determination of the Reflection Coefficients and Insertion Loss of a Waveguide Junction," Jour. App. Phys., V24, pp. 1046-1050, Aug. 1953.

[8] G. A. Deschamps, "A Hyperbolic Protractor for Microwave Impedance Measurements and Other Purposes," Federal Telecommunications Labs., 1953.

LOW NOISE 400-Mc REACTANCE AMPLIFIERS*

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I. INTRODUCTION

The inherent simplicity and low noise qualities of reactance amplification are extremely attractive for use in receiving systems where the ultimate in sensitivity is required. Examples of such systems are found in the fields of radar, communication, and radio astronomy. Reactance amplification is here defined as that type of amplification obtained by the use of a nonlinear capacitance or inductance. Another common name for this type of amplification is parametric amplification.

This paper describes three types of 400-Mc reactance amplifiers. Construction details will be discussed and performance data shown for three modes of operation. Reactance amplification is obtained by the use of a nonlinear capacitance or Varactor manufactured by the Bell Telephone Laboratories and supplied through the courtesy of the Signal Corps.

The three modes of operation to be discussed are the sum-frequency, two-port difference-frequency and one-port difference-frequency modes. These modes of operation are shown schematically in Figure 1. In the sum frequency mode, the output signal frequency is the sum of the pump frequency and the input signal frequency. In the two-port difference-frequency mode the output signal frequency is the difference between the pump frequency and the input signal frequency. In the one-port difference-frequency mode, the output signal is at the same frequency as the input signal and both appear at the same port. In this mode, a tuned circuit is provided across the diode terminals at the idler or difference frequency.

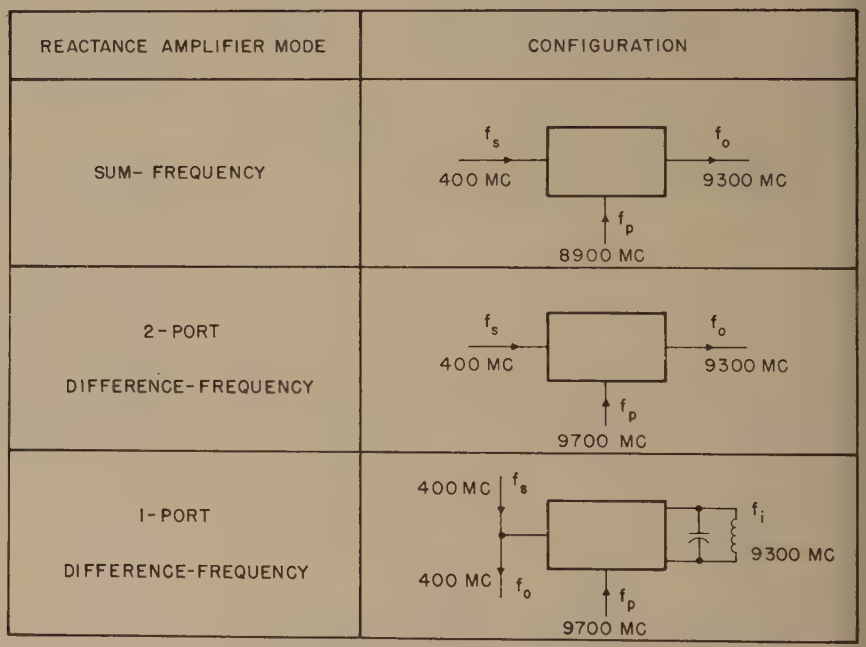

Figure 1 — Schematic representations of the three modes of operation.

II. SUM FREQUENCY MODE

The sum-frequency mode is characterized by a fixed theoretical available power gain, absolute stability, and broad bandwidth. The theoretical available power gain, (for an ideal diode) is given by the ratio of the output sum frequency to the input signal frequency. All difference-frequency modes possess a negative resistance characteristic that results in a constant voltage gain times bandwidth product and potential instability. However, the two-port difference-frequency mode has a higher voltage gain-bandwidth product than the one-port difference-frequency mode. Basically, all three modes exhibit low noise amplification.

In the theoretical analysis of the reactance amplifier, it is assumed that the only voltages that exist across the diode are at the three critical frequencies shown in Figure 1 for each mode of operation. In the sum-frequency mode, for example, a short circuit must appear across the Varactor terminals at the difference-frequency to obtain true sum-frequency operation. It will be shown subsequently how this is accomplished in practice.

Figure 2 is a block diagram of a balanced 400-Mc sum-frequency reactance amplifier. A balanced configuration was used because of the inherent isola-

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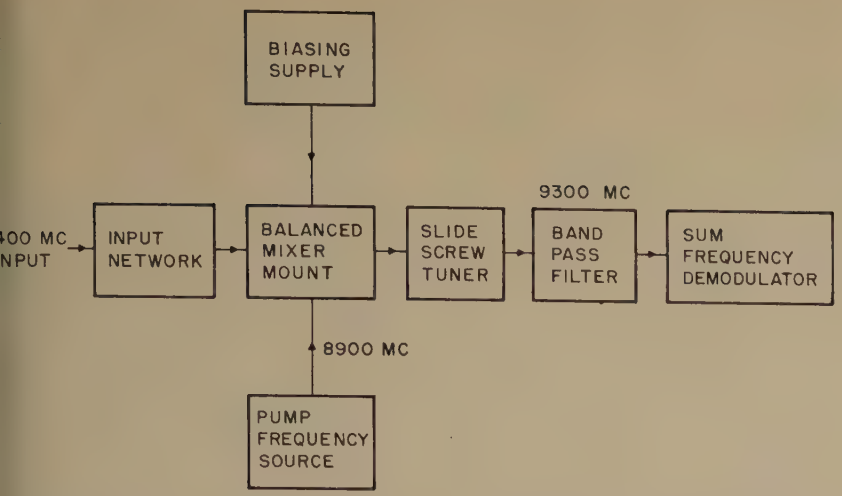


Figure 2 — Block diagram of the 400-mc sum-frequency reactance amplifier.

on obtainable between the pump ort and the sum-frequency port. The herent isolation affords two advanges since (1) the pump source is upled directly to the diodes, which sults in a low pump power requirent, and (2) the pump port is isoted from the sum-frequency port ereby minimizing leakage of the mp into the sum port and vice rsa. The success we had previously tained with a balanced 1-Mc prototype sum-frequency reactance amplier was also a factor in the choice of balanced configuration.

An X-band pump frequency was ed because, for this frequency, a od compromise between second age mixer noise and high availle gain (in the sum mode) is obinable. In either of the difference equency modes, the higher the pump equency the lower the noise factor. us, an X-band pump frequency is arly optimum for all three modes.

The amplifier consists of a conventional X-band magic-tee balancedixer containing the Varactor diodes. a conventional X-band mixer usg mixer diodes, such as the 1N23E, X-band local-oscillator signal is ixed with an X-band input signal generate a lower difference frequency or intermediate frequency at e output. The mixer mount in the actance amplifier is basically opated in a reverse manner from the nventional mixer. The 400-Mc int signal is applied to the normal output port, the 9300-Mc sumequency output is taken from the rmal X-band signal input port, the 00-Mc pump frequency is coupled the normal local-oscillator port, d the Varactors replace the mixer odes. The polarity of the Varactor diodes in the mount depends on whether the 400 Mc input signal is applied in a balanced or unbalanced fashion. Out of phase Varactors are compatible with an unbalanced input and in-phase Varactors with a balanced input. The 400-Mc input network accomplishes two purposes. It transforms the generator impedance to the optimum source impedance required by the reactance amplifier, and it resonates with the capacitance of the mount (which includes the X-band bypass capacitance and the average capacitance of the Varactors).

The slide-screw tuner matches the output of the reactance amplifier to the nominally matched input of the X-band filter. In conjunction with the X-band sum-frequency filter, the tuner is also used to present a low impedance across the Varactors at the difference frequency of 8500 Mc. The proper setting of the tuner is accomplished by applying a 400-Mc signal to the input and adjusting the slide-screw tuner for a peaked response as observed on the sum-frequency demodulator. There are several lateral positions of the tuner where a peaked response can be obtained. (These are located approximately a half guide wavelength apart at the sum frequency.) The proper peak setting of the tuner is that which produces no oscillations when the pump power is increased, since the stable sum-frequency mode is then provided with a match at its output port, whereas the termination across the diode at the difference-frequency approaches a short circuit. Intermediate positions of the slide screw represent a combination sum- and difference-frequency mode of operation.

The band-pass filter is tuned to the sum-frequency of 9300 Mc and has a 3-db bandwidth of about 120 Mc and an insertion loss of about 0.1 db. The bandwidth of the filter is determined by overall system bandwidth requirements and by the amount of rejection required to minimize pump leakage into the sum-frequency demodulator. The sum-frequency demodulator consists of a short-slot hybrid balanced mixer, an X-band local-oscillator, and a 30-Mc receiver. The pump source consists of a V58 Varian klystron, an isolator, and an E-H tuner. The E-H tuner maximizes the pump frequency voltage across the Varactors. The actual pump power delivered to the diodes is about 20 to 30 mw, most of which is absorbed in the diode series resistance.

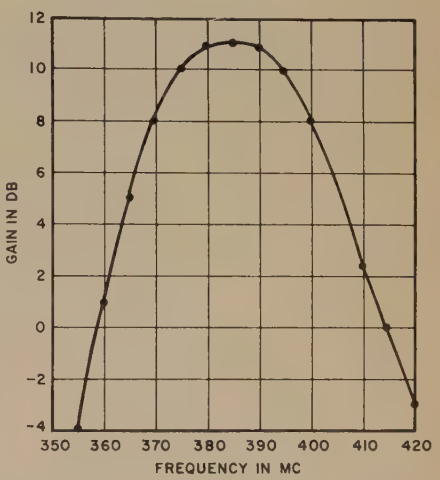


Figure 3 — Gain vs. frequency characteristic of the sum-frequency reactance amplifier.

Figure 3 is a plot of gain vs. frequency for a typical sum-frequency reactance amplifier. A bandwidth of 30 Mc and a gain of 11 db are indicated in the figure. The spurious responses are down at least 15 db from the signal response. Figure 4 is a plot of noise factor vs. frequency for the sum-frequency reactance amplifier.

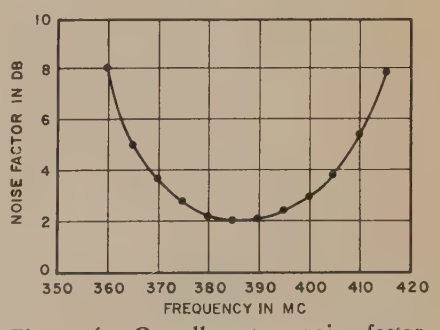


Figure 4 — Overall system noise factor vs. frequency for the sum-frequency reactance amplifier. (The X-band demodulator noise factor is 7.5 db).

The noise factor plot was made on a point-by-point basis with a c-w signal generator, and checked at the center frequency by the use of a helix type gas-discharge noise generator. The measured noise factor is 1.9 db at the center frequency. This represents an overall effective input noise temperature of 160 degrees K, of which 112 degrees K are due to the X-band second-stage noise temperature and the remaining 48 degrees K are due to input circuit and Varactor losses. Thus, the major contribution to the overall noise temperature comes from the X-band demodulator. Improved mixer crystals will minimize this contribution and greatly reduce the overall noise temperature of the sum-frequency mode. Figure 5 is a plot of the linearity of the sum-frequency reactance amplifier. The amplifier is linear from thermal noise up to an input signal level of about 3 mw, which represents a dynamic range of about 116 db for a post-receiver bandwidth of 2 Mc.

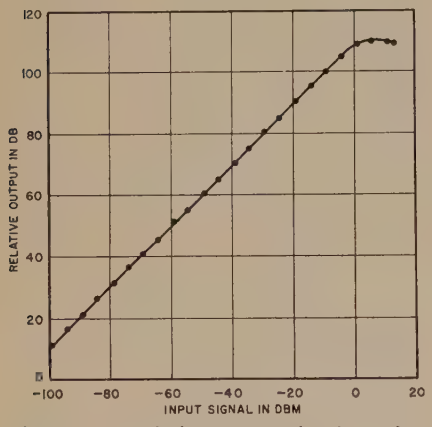


Figure 5 — Relative output level vs. input level for the sum-frequency mode.

III. MEASUREMENT OF AVAILABLE GAIN IN A TWO-PORT REACTANCE AMPLIFIER

The measurement of the available gain of the reactance amplifier stage is not straightforward and will be described. With presently available noise generators, it is relatively easy to measure noise factor with good precision. The measurement of the available gain of the reactance amplifier stage, however, is complicated, since the gain occurs between terminals at which the signal is at different frequencies. With conventional signal generators, the output calibrations of the two different generators (one at the signal frequency and the other at the sum frequency) are such that substantial errors can occur when using a direct insertion gain measurement.

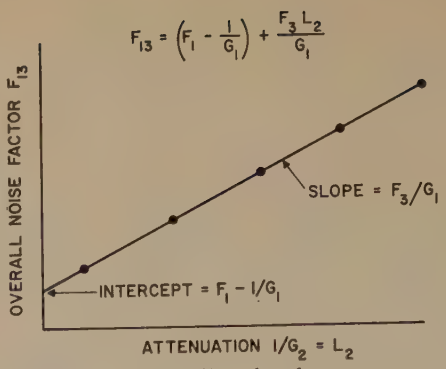


Figure 6 — Overall noise factor vs. attenuator loss.

A technique has been devised to accurately measure the available gain by an indirect method based on the measurement of noise factor. The only additional component required is a precision attenuator that is inserted between the mixer and filter. A measurement of overall noise factor is then made as a function of the precision attenuator setting. The result is shown in Figure 6, where overall noise factor is plotted as a function of attenuation. Expressing the overall noise factor in terms of the first stage, attenuator stage, and mixer stage noise factors, then, by a measurement of the slope of the line drawn through all the points and a separate measurement of the X-band mixer noise factor, one obtains the available gain. The technique has led to accurate and repeatable measurements of the available gain of both the sum and two-port difference-frequency reactance amplifiers without the need of separating networks.

IV. TWO-PORT DIFFERENCE-FREQUENCY MODE

It was previously stated that the sum-frequency mode has a theoretical gain equal to the ratio of output to input frequencies. As has been shown, this limited gain results in a large second-stage noise temperature contribution. The difference-frequency modes, however, are characterized by a constant voltage gain times bandwidth product and consequently do not possess a finite gain limitation. Hence, the gain can be made sufficiently high to mask out almost all the second-stage noise temperature contributions. The basic configuration of the sum-frequency mode represents a two-port difference-frequency reactance amplifier when the pump frequency is changed to 9700 Mc. The output frequency of 9300 Mc is then the difference between the pump and the input frequency. For this mode of operation ferrite isolator is inserted between t filter and mixer to obtain more stab operation. Typical results we have o tained with the two-port differenc frequency mode are gains of abo 18 db over a 3-db bandwidth of 2 Mc with an overall noise factor l than 1.0 db.

V. ONE-PORT DIFFERENCE-FREQUENCY MODE

A version of the reactance amplifi that requires fewer components is t one-port difference-frequency mo This type of operation is obtained b replacing the tuner, filter, and mix combination by a cavity tuned to th idler or difference frequency of 93 Mc. The results we have obtaine with this mode of operation are gai of about 20 db over a bandwidth 0.4 Mc with a noise factor less tha 1.0 db. The operational stability this mode has not approached th stability achieved in the sum-frequen mode or the two-port difference-fr quency mode. The stability could b improved by the use of a low-lo non-reciprocal device which, unfo tunately, is not presently available f operation at 400 Mc. Figure 7 is table showing the comparison of th results obtained in the three mod of operation.

TYPE OF MODE	GAIN (DB)	OVERALL NOISE FACTOR (DB)	BANDWIDT (MC)
SUM FREQUENCY	11	1.9	30
TWO-PORT DIFFERENCE FREQUENCY	18	<1	2.5
ONE-PORT DIFFERENCE FREQUENCY	20	<1	0.4

Figure 7 — Relative performance data f the three modes of operation.

VI. NOISE-FACTOR MEASURE MENT PROBLEMS

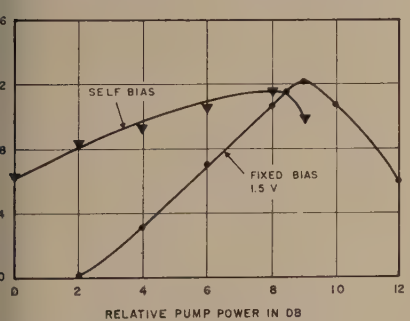
The difficulty involved in measu ing the noise factor of the differenc frequency type of reactance amplifi should be emphasized at this point. I utilizing the helix gas-discharge typ of noise generator, there are sl gh SWR variations when the lamp turned on and off. These changes SWR are typically from a value of 1.0 with the lamp on to about 1.15 wit the lamp off. In the difference-fr quency type of reactance amplifie these variations in SWR are sufficie to cause considerable gain variation In fact, the amplifier can change fro a stable to an unstable state with th small change in SWR. In all our nois factor measurements for the differenc

requency modes, a 10-db pad was inerted between the amplifier and the oise generator to reduce the SWR ariations. Extreme caution must be xercised when making accurate measrements of the noise factors of differnce-frequency reactance amplifiers.

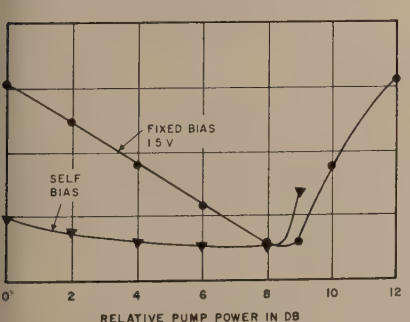
VII. OPERATIONAL STABILITY DATA

Additional measurements were made n the reactance amplifiers to deterine variations in gain and noise facor caused by changes in various parmeters. A critical parameter is the ump power level and, consequently, plot was made of gain and noise facor as a function of this parameter. Data were also taken to compare fixed ias with self-bias operation for the m-frequency mode and the two-port ifference-frequency mode. A curve is ot shown for the one-port differenequency mode because measurements ere not repeatable.

Figure 8 is a plot of gain vs. relave pump power for the sum-freuency mode. A greater gain was ossible with fixed bias, but this gain oint had a degraded noise factor. one adjusts the amplifier for optium noise factor with bias and then emoves the bias, the self-biasing acon yields the identical bias point. can be seen that self bias yields a ss critical amplifier. Figure 9 is a ot of noise factor vs. relative pump ower for the sum-frequency reac-



gure 8 — Gain vs. pump power for the sum-frequency mode.



gure 9 — Overall system noise factor vs. pump power for the sum-frequency mode.

tance-amplifier. Again, the superiority of self bias can be seen. Figure 10 is a plot of gain vs. relative pump power for the two-port difference-frequency mode for self and fixed bias. Figure 11 is a plot of noise factor vs. relative pump power for the two-port difference-frequency mode.

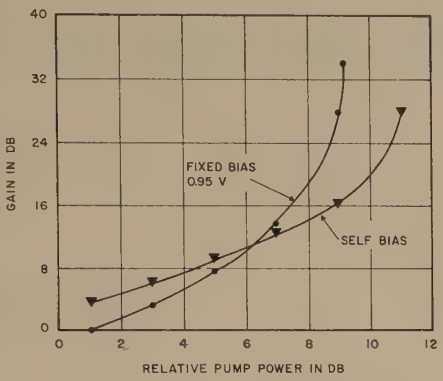


Figure 10 — Gain vs. pump power for the two-port difference-frequency mode.

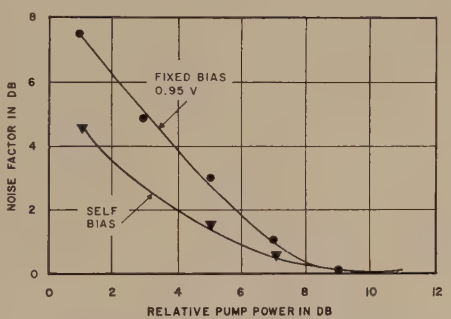


Figure 11 — Overall system noise factor vs. pump power for the two-port difference-frequency mode.

VIII. CONCLUSIONS

It can be concluded that stable operation has been obtained in the sum-frequency mode and the two-port difference-frequency mode with corresponding low noise factors. The fact that low noise operation is obtainable without resorting to refrigeration techniques, and that these amplifiers can withstand large signal powers without a resultant degradation in performance, is of prime importance in system considerations.

IX. REFERENCES

A list of references follows that is pertinent to the work described above. References 7 and 8 are available from ASTIA, Arlington Hall Station, Arlington 12, Virginia.

REFERENCES

1. A. van der Ziel, "On the Mixing Properties of Nonlinear Condensers," Journal of Applied Physics, Vol. 19, p. 999-1006, November 1948.

2. J. M. Manley and H. E. Rowe, "Some General Properties of Nonlinear Elements — Part I. General Energy Relations," Proc. IRE, vol. 44, p. 904-913, July 1956.

3. B. Salzberg and E. W. Sard, "A Low-Noise Wide-Band Reactance Amplifier," Proc. IRE, Vol. 46, No. 6, p. 1303, June 1958.

4. A. Uhlir, Jr., "The Potential of Semiconductor Diodes in High-Frequency Communications," Proc. IRE, Vol. 46, No. 6, p. 1099-1115, June 1958.

5. D. Leenov, "Gain and Noise Figure of a Variable-Capacitance Up-Converter," The Bell System Technical Journal, Vol. 37, No. 4, p. 989-1008, July 1958.

6. H. Heffner and G. Wade, "Gain, Bandwidth, and Noise Characteristics of the Variable-Parameter Amplifier," Journal of Applied Physics, Vol. 29, p. 1321-1331, September 1958.

7. R. Gardner, J. C. Greene, P. P. Lombardo, E. W. Sard, and K. Siegel, "First Quarterly Progress Report — "Application of Semiconductor Diodes to Low-Noise Amplifiers, Harmonic Generators, and Fast-Acting TR Switches," Report No. 4589-M-1, Airborne Instruments Laboratory, September 1958.

8. R. Gardner, J. C. Greene, P. P. Lombardo, B. Salzberg, and E. W. Sard, "First Quarterly Progress Report On Application of Semiconductor Diodes to Microwave Low-Noise Amplifiers and Harmonic Generators," Report No. 5872-1-1, Airborne Instruments Laboratory, October 1958.

RESONANT MODES AND FREQUENCIES OF A CIGAR-SHAPED CAVITY

Dennis F. Meronek*
J. Van Bladel**

The purpose of this article is to present data on the modes of revolution of the cavity depicted in Figure 1, and, in so doing, to add a paragraph to the catalogue of solved resonator configurations.

Modes of revolution are characterized by the ϕ independence of the electric and magnetic fields (ϕ is the azimuthal angle). In a region bounded by any surface of revolution such modes fall into two categories.[1]

1. *Meridian magnetic modes*

For modes of revolution the electric field is given by $g_m(r, z)\,\bar{u}_\phi$, a vector which is perpendicular to the meridian plane[2] (See Figure 2). The associated magnetic field is given by curl $(g_m\bar{u}_\phi)$. This vector lies entirely in the meridian plane, a property which justifies the name meridian magnetic given to this class of modes. The function $g_m(r, z)$, which determines the structure of the mode, is one of the solutions of the differential equation

$$\frac{\partial^2 g_m}{\partial r^2}+\frac{1}{r}\frac{\partial g_m}{\partial r}+\frac{\partial^2 g_m}{\partial z^2}+\left(k_m-\frac{1}{r^2}\right)g_m=0 \qquad (m=1,2,3,\ldots) \quad (1)$$

with the boundary conditions: $g_m=0$ on the axis and on the contour (C). There is a discrete infinity of values

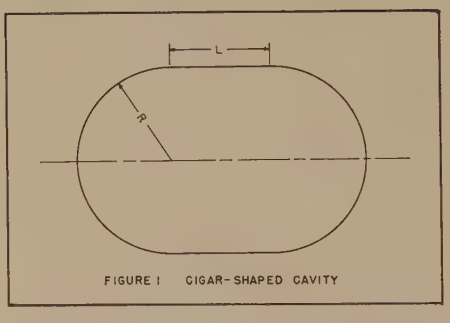


FIGURE 1 CIGAR-SHAPED CAVITY

of k_m^2 (the eigenvalues), and corresponding g_m (the eigenfunctions), for which this differential equation has a solution different from zero. Each g_m corresponds to a different mode, with resonant frequency $\frac{k_m}{2\pi\sqrt{\epsilon\mu}}$. ($\epsilon$ and μ refer to the medium contained in the cavity.) This article investigates the two lowest meridian magnetic modes of the cigar-shaped cavity, i.e., the modes corresponding to the two lowest values of k_m and, consequently, of the resonant frequency.

2. *Meridian electric modes*

For this class of modes the magnetic field is given by $h_m(r, z)\bar{u}_\phi$. The associated electric field is found from curl$(h_m\bar{u}_\phi)$, a vector situated in the meridian plane. The mode generating function h_m satisfies (1), but the boundary conditions are now $\frac{\partial(h_m r)}{\partial r}=0$ on contour (C), $h_m=0$ on the axis. The differential problem again has an infinite number of solutions, with corresponding modes and resonant frequencies $\frac{k_m}{2\pi\sqrt{\epsilon\mu}}$. The two lowest meridian electric modes of the cigar-shaped cavity will be investigated in this article.

The mathematical problem consists of determining the two lowest eigen-values and eigenfunctions of equation (1) with accompanying boundary conditions. Details on the method of solution can be found elsewhere.[3] Briefly, this method consists of finding the eigenvalue as the stationary value of a certain expression, replacing differential operators by difference operators in the latter and solving the resulting large number of linear algebraic equations by iteration. This time-consuming procedure was greatly accelerated by the

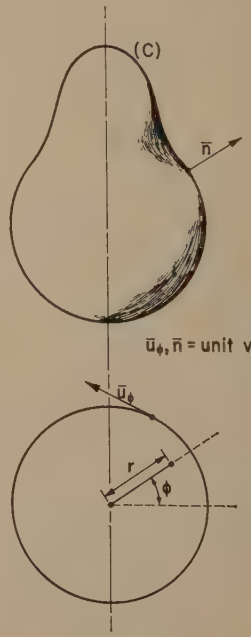


FIGURE 2. CAVITY OF REVOLUTIO

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**Department of Electrical Engineering, University of Wisconsin.

se of an IBM 650 computer. The esults of the still long computations 50 hours of machine time) are pre-ented in Figures 3 to 6. Figures 3 nd 4 show the variation of the reson-

nt frequency as the $\frac{\text{length}}{\text{diameter}}$ ratio of

ne cavity varies. The limits $\frac{L}{D} = 0$

nd ∞ correspond, respectively, to a pherical cavity and an infinitely long ylindrical cavity. Several experimental neasurements were made, and the re-ults are plotted as small circles on hese curves.

Figure 5 shows a typical distribu-ion of the electric field $g_m \bar{u}_\phi$ over ne quadrant of the meridian cross-sec-ion (the distribution in the other uadrants is either symmetrical or anti-ymmetrical). The variation of the urface magnetic field has also been ndicated. This is of importance for etermining the best location of a oupling hole. Figure 6 shows a typi-al distribution of the magnetic field hroughout a quadrant and provides, gain, useful information for the op-imum location of holes, coupling loop ntennas, and the like.

[1] J. Bernier, "On Electromagnetic Res-nators," *Onde Electrique,* (August-Sep-mber, 1946), 26, 305-17. For general ackground on resonant modes in cavities, ee P. Morse and H. Feshbach, *Methods of heoretical Physics,* Chap. 13.

[2] Any plane containing the axis of revo-ution.

[3] Dennis F. Meronek, "Resonant Modes nd Frequencies of a Cigar-Shaped Cavity," M. S. thesis, University of Wisconsin, 1958.

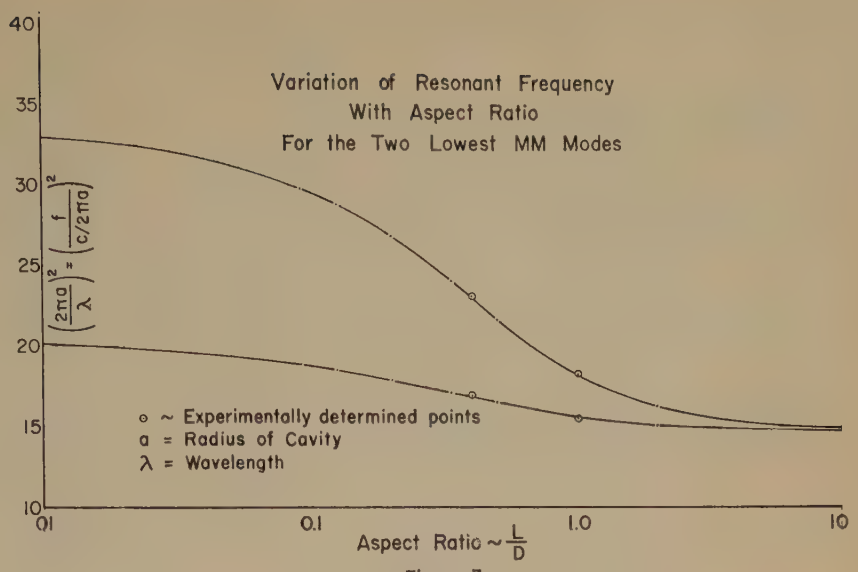


Figure 3

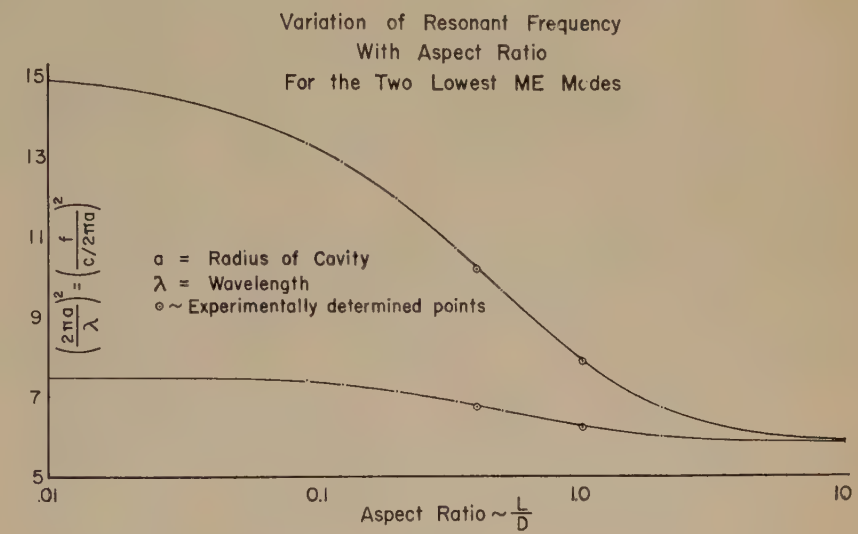


Figure 4

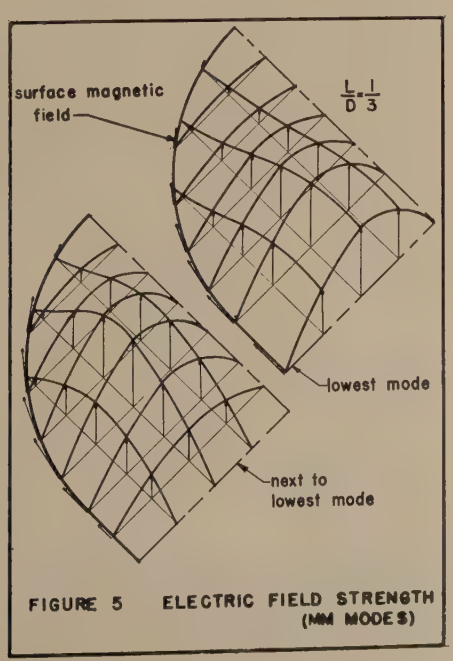


FIGURE 5 ELECTRIC FIELD STRENGTH (MM MODES)

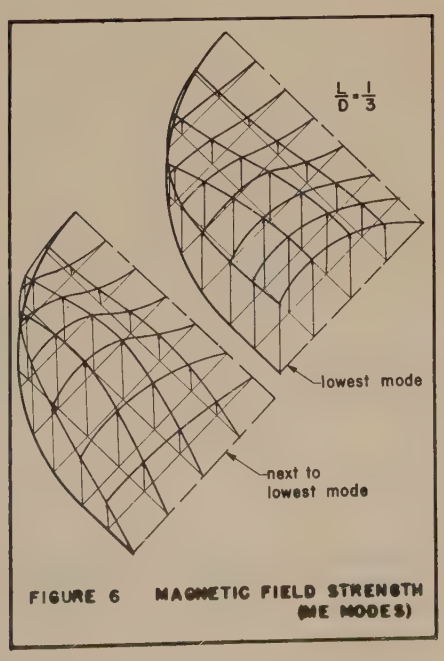


FIGURE 6 MAGNETIC FIELD STRENGTH (ME MODES)

DIRECTIONAL COUPLER DESIGN NOMOGRAMS

Tore N. Anderson
Airtron Inc.

Definitions

Directional couplers are specified by two quantities, coupling which is a measure of the energy sampled from the main guide, and directivity which measures the directional properties of the coupler.

Coupling

$$C = 10 \log_{10} \frac{P_1}{P_f}$$

P_1 = Power in main guide
P_f = Power in secondary guide flowing in desired direction
P_b = Power in secondary guide flowing in undesired direction

Directivity

$$D = 10 \log_{10} \frac{P_f}{P_b}$$

TABLE I

Type of Coupler	*Coupling*	*Range for Constant Coupling*	*Maximum Directivity*	*Range for Directivity 20 db*
Two Hole (Bethe) Narrow wall to narrow wall	20 db	12 percent ± .7 db	37 db	8 percent
Schwinger Reverse Coupler	20 db	25 percent ± 1.5 db	30 db	25 percent
Broad wall to narrow wall	20 db	15 percent ± .2 db	20 db	15 percent
Moreno Crossed Guide	20 db	15 percent ± .1 db	23 db	(for 15 db Directivity) 12 percent
Riblet-Saad one pair of elements — broad wall to broad wall	20 db	15 percent ± .25 db	54 db	25 percent

FOUR NOMOGRAMS ARE presented here which provide a quick approximate method for determining the coupling dimensions for the four basic coupler structures:

1. The Sidewall (Bethe-Hole) Coupler (Narrow wall to narrow wall)
2. The Schwinger Reversed Coupler (Broad wall-narrow wall)
3. The Moreno Cross Guide Coupler
4. The Riblet-Saad Coupler (Broad wall to broad wall)

These four couplers fit the largest bulk of directional coupler designs and these curves provide the waveguide circuit designer with the approximate hole dimensions which can then be readily adjusted by the famous technique of Dr. Riblet's of filing the holes to the exact coupling values desired.

Since the waveguide aspect ratios and wall thicknesses in proportion to the waveguide dimensions will vary from waveguide size to waveguide size, and these curves have been normalized to an idealized set of wavguides, the results that are obtainable with these are only approximate however, they are more than accurate for an initial determination of a particular coupler design and adjustments can then be made readily to bring the coupling value within the desired value over the band of interest.

A short description of each coupler type and its characteristics follows with a table of the performance which can be expected for the various coupler designs.

1. *Bethe-Hole Coupler (Narrow wall to narrow wall)*

This coupler is a very common structure for high powered applications since the coupling apertures are in the narrow wall and do not introduce any serious electric field breakdown problems. The basic theory for this has been worked out by Bethe, although generally this is called a Sidewall Coupler, and I feel that proper credit should be given to Bethe for his contributions to this coupling design. Arrays of holes of this type can be used in more sophisticated designs to cover wider bandwidths than are possible with two quarterwave spaced holes.

2. *Schwinger Reversed Coupler (Broad wall to narrow wall)*

The Schwinger coupler has an interesting configuration which finds application in solving packaging problems. The coupling direction is reversed from that in the main line which also sometimes proves useful. With the coupling apertures in the narrow wall of the high powered line, this structure can also be used in high powered applications, although its more normal usage, the coupling apertures being in the middle of the broad wall, do limit the power handling capacity of the main guide.

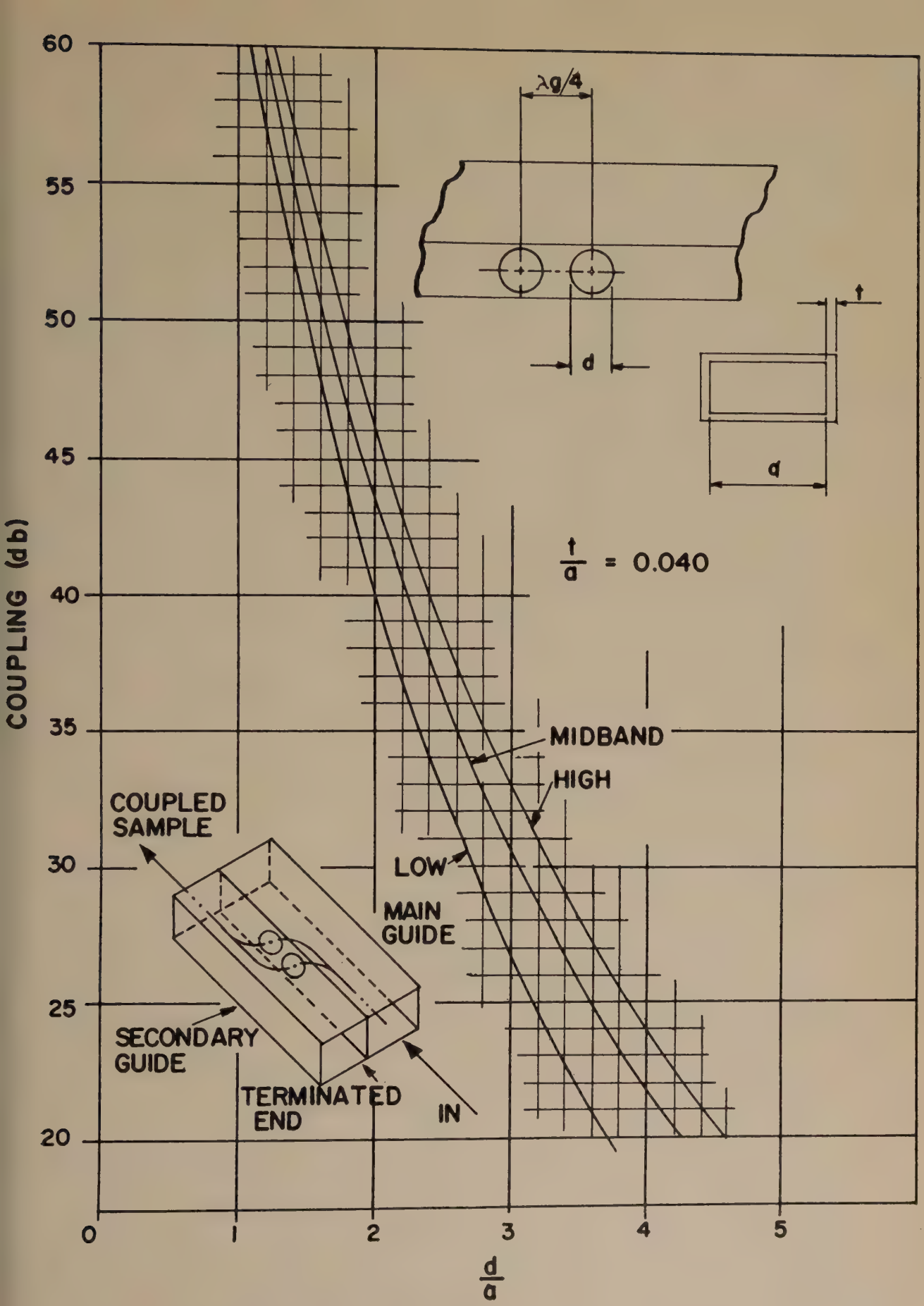
3. *Moreno Cross Guide Coupler*

The Moreno coupler is another useful configuration for packaging in that the secondary guide and its termination run at right angles to the main waveguide run. The power handling capacities of this structure is moderate with careful workmanship.

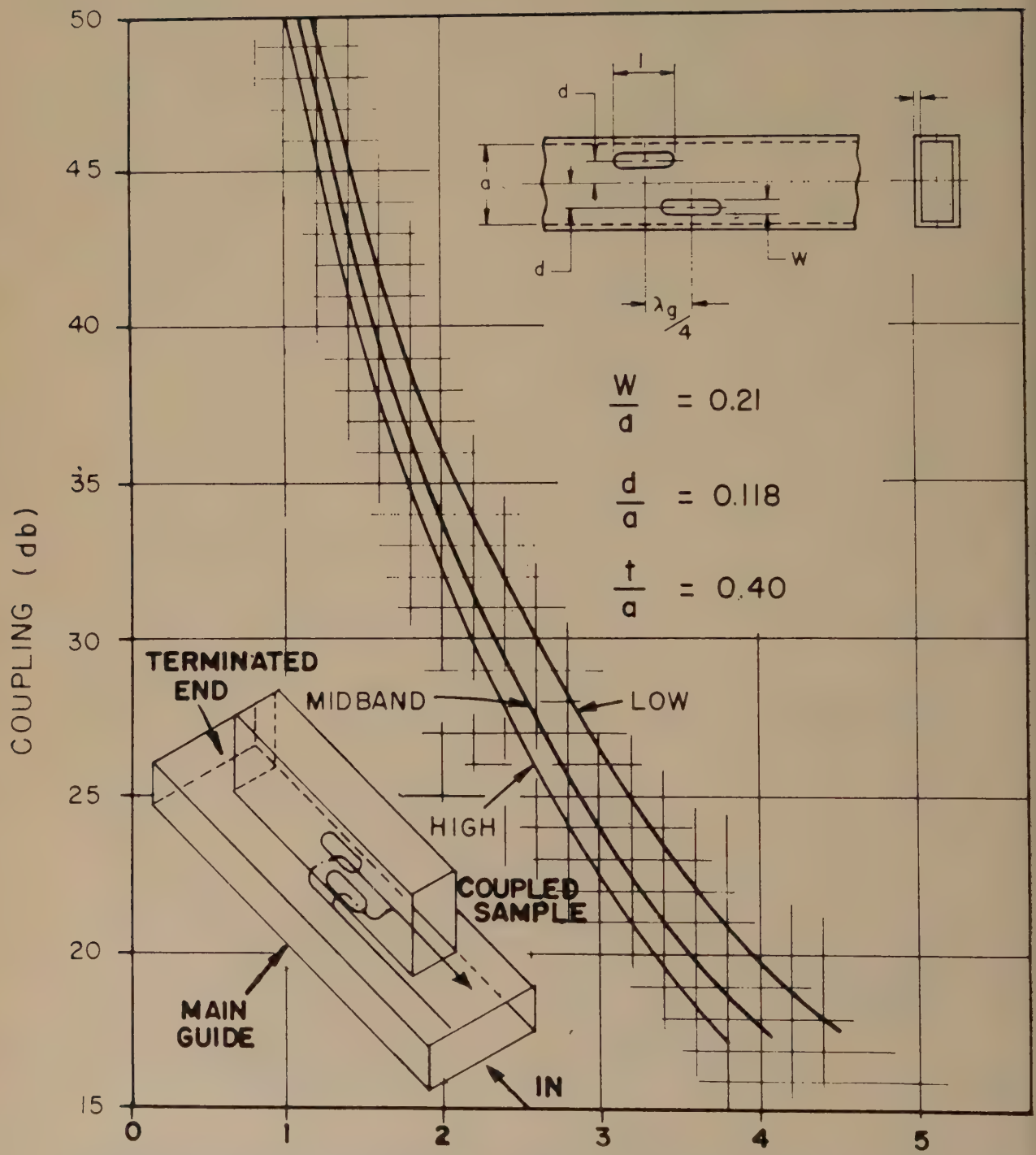
4. *Riblet-Saad Coupler (Broad wall to broad wall)*

This coupler can be arranged in pairs of tee slots to provide very tight couplings, less than 10 db coupling being the more common application of this coupler structure.

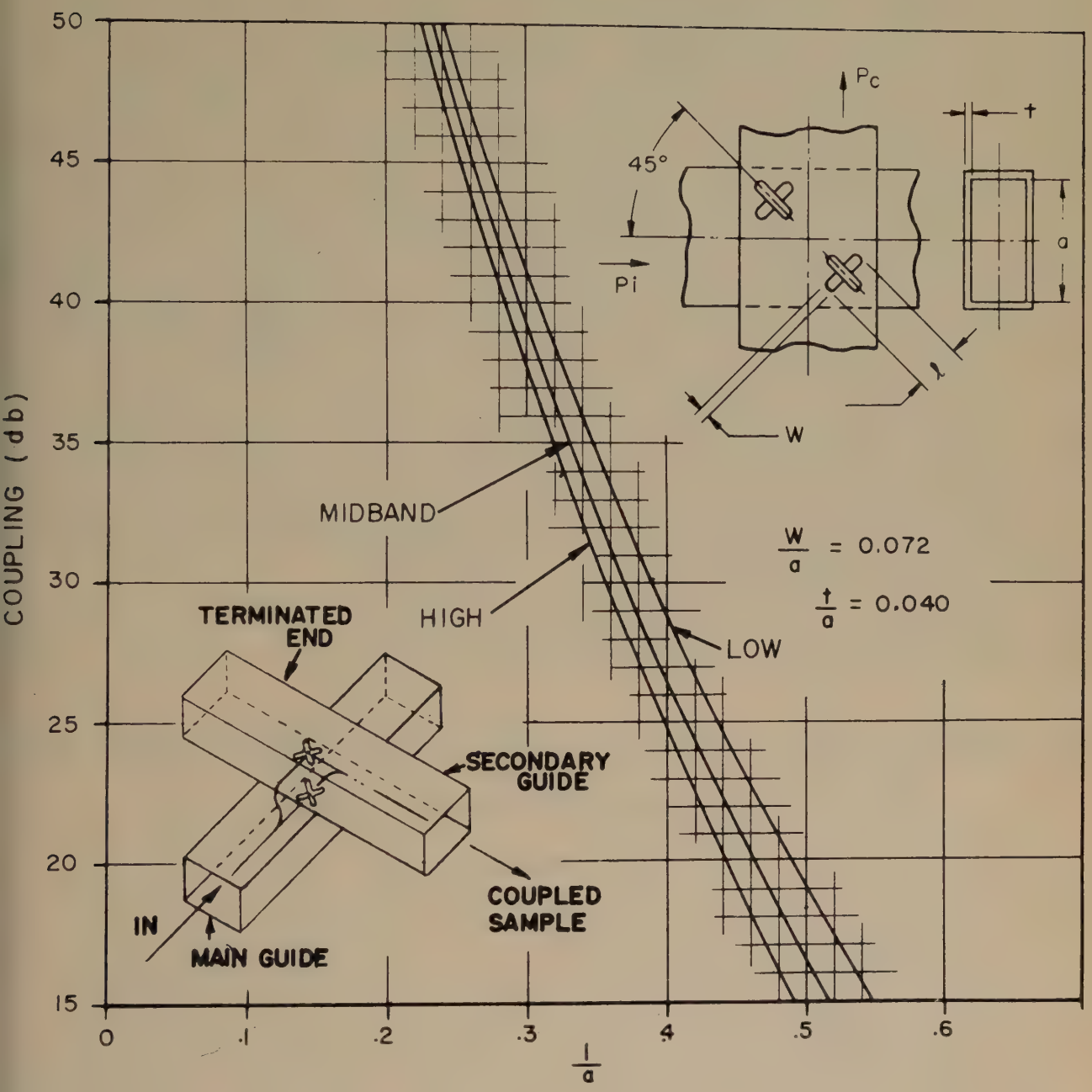
Subsequent issues of *the microwave journal* will contain nomograms for determining couplings for multiple arrays of the applicable types.



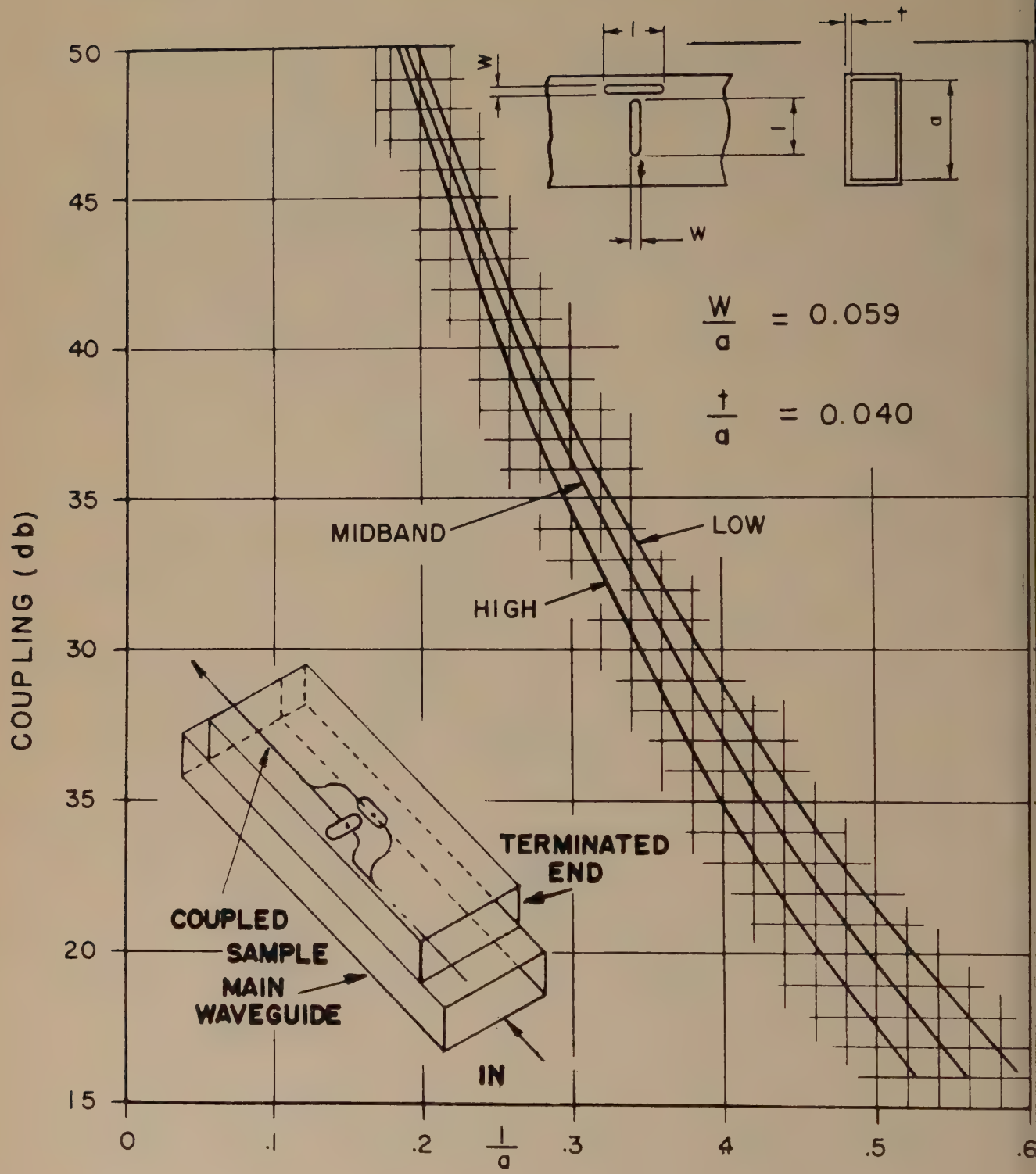
Normalized coupling curves for two-element coupler using round holes in narrow side of waveguide; 2 to 1 aspect ratio.



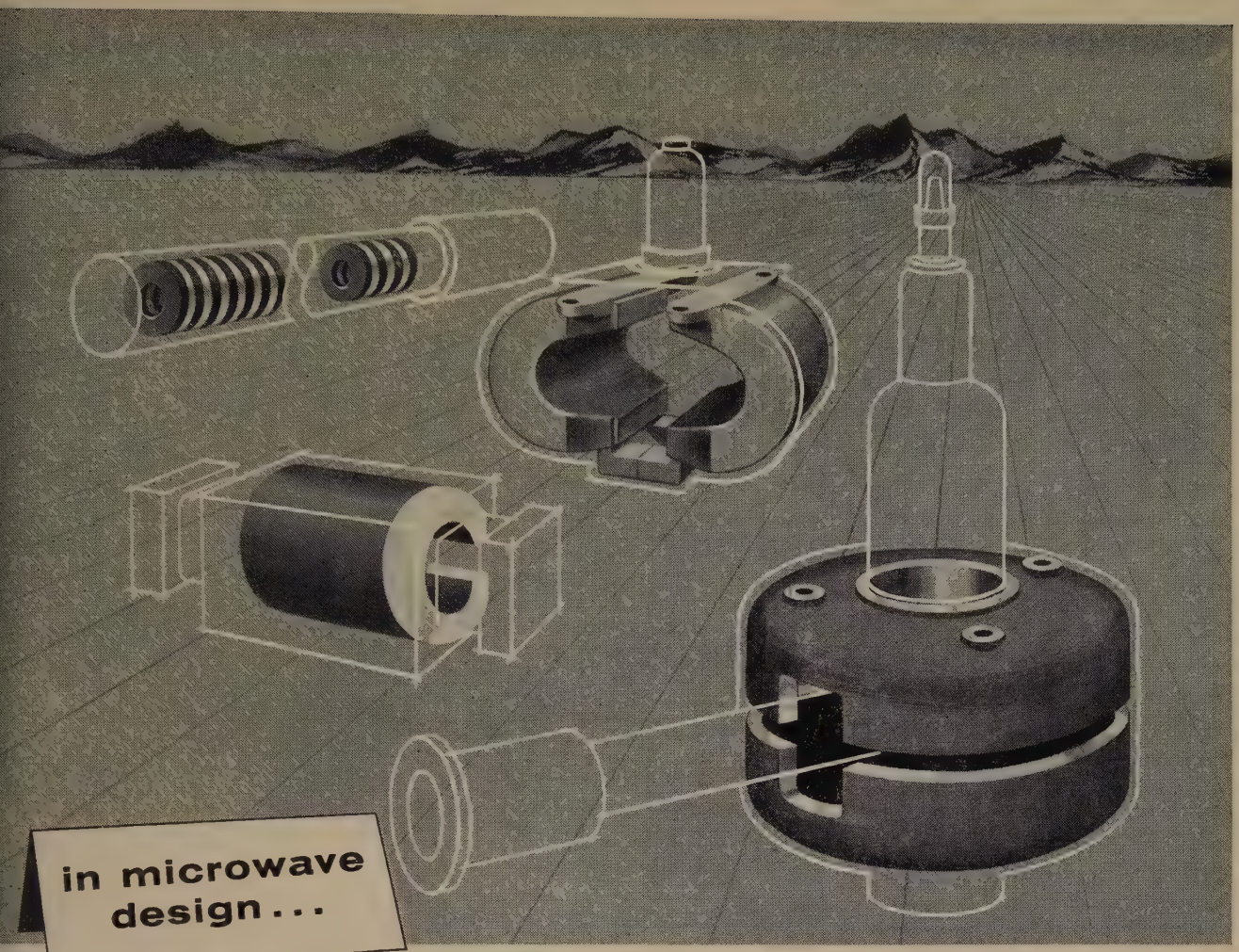
Normalized coupling curves for Schwinger reversed phase directional coupler; 2 to 1 aspect ratio.



Normalized coupling curves for Moreno cross guide directional coupler; 2 to 1 aspect ratio.



Normalized coupling curves for one pair of Riblet type tee slots in broad wall of waveguide; 2 to 1 aspect ratio.



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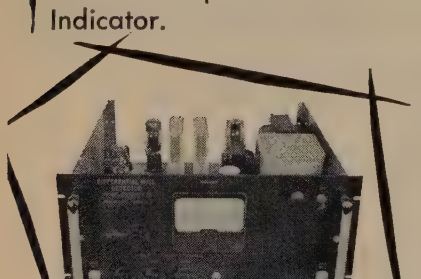

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Advance Program

1959 PGMTT NATIONAL SYMPOSIUM

PAINE HALL · Harvard Music Building
Harvard University, Cambridge, Mass.

Registration: 8:00-8:45 A.M., Monday, June 1, 1959

SESSION I FILTERS and COMPONENTS
Chairman: R. W. P. King, Harvard University, Cambridge, Mass.
Opening Addresses: W. L. Pritchard, Symposium Chairman, Raytheon Mfg. Co
T. S. Saad, Chairman PGMTT, Sage Laboratories; McGeorge Bundy, Dean
the Faculty of Arts and Sciences, Harvard University.

I-1 Invited Paper "Directional Couplers An Example of Microwave Developments" 9:00-9:30 A.M.
Harold A. Wheeler, Wheeler Laboratories, Inc., Great Neck, N.Y.

I-2 "A Constant Resistance Microwave Filter" 9:30-9:45 A.M.
J. Reed, J. Child and H. Thomas, Raytheon Mfg. Co., Wayland, Mass.

I-3 "The Design and Measurement of Two Broadband Coaxial Phase Shifters" 9:45-10:00 A.M.
C. F. Augustine and J. Cheal, Bendix Aviation Corporation, Research Laboratori
Division, Detroit, Mich.

I-4 "Microwave Phase Shifters" 10:00-10:15 A.M.
David L. Fye, Electromagnetic Radiation Laboratory, Air Research and Develo
ment Command, Bedford, Mass.

INTERMISSION 10:15-10:35 A.M.

I-5 Invited Paper "Dissipation Effects in Microwave Filters" 10:35-11:05 A.M.
Seymour B. Cohn, Stanford Research Institute, Menlo Park, Calif.

I-6 "Wide-Stop-Band Waveguide Filters" 11:05-11:20 A.M.
B. Schiffman* and S. B. Cohn, Stanford Research Institute, Menlo Park, Calif.
*Now at Varian Associates

I-7 "Tunable Microwave Filters" 11:20-11:35 A.M.
F. Torgow and D. Jacenkó, Polytechnic Institute of Brooklyn, Brooklyn, N.Y.

I-8 "A Transmission Line Backward Wave Filter" 11:35-11:50 A.M.
M. F. Hines and F. T. Harkless, Bell Telephone Laboratories, Murray Hill, N.J.

SESSION II MICROWAVES I Monday, June 1, 1959 at 2:00 P.M.
Chairman: Kiyo Tomiyasu, G.E. Microwave Laboratory, Palo Alto, Calif.

II-1 Invited Paper "A Survey of the Microwave Research in Japan in 1958" 2:00-2:30 P.M.
Isao Someya, Secretary of the PGMTT in Tokyo

II-2 "Determination of Some Electrical Properties of a Gas-Detonation by Microwa
Techniques" 2:30-2:45 P.M.
Bernard Hayes, Los Alamos Scientific Lab., Univ. of Calif., Los Alamos, N.M.

II-3 "Microphony in Waveguide" 2:45-3:00 P.M.
I. Goldstein and S. Soorsoorian, Missile Systems Division, Raytheon Mfg. C
Bedford, Mass.

II-4 "Tunable Spherical Cavity Resonators" 3:00-3:15 P.M.
F. Richter* and A. F. O'Brien, Jr., Raytheon Mfg. Co., Bedford, Mass.
*Now at Ewen-Knight Corp.

INTERMISSION 3:15-3:35 P.M.

II-5 "Use of Partially-Filled Dielectric Coaxial Lines in Non-Reciprocal Devices" 3:35-3:50 P.M.
G. S. Heller and J. S. Coe, MIT Lincoln Labs., Lexington, Mass.

II-6 "Coupling of Multiple Cavity Systems" 3:50-4:05 P.M.
G. S. Kino and M. A. Allen, Microwave Lab., Stanford Univ., Stanford, Calif.

II-7 "Dielectric Leading and Tapered Field Effects in Ferrite Devices Using Perturb
tion Methods" 4:05-4:20 P.M.
R. F. Soohoo, MIT Lincoln Laboratory, Lexington, Mass.

II-8 "Theoretical Limitations of Ferrite Amplifier Performance" 4:20-4:35 P.M.
R. W. Damon and J. R. Eshbach, General Electric Research Lab., Schenectady, N.

II-9 "TF_{01} Shuttle Pulse Measurements in Multi-Mode Circular Waveguide" 4:35-4:50 P.M.
W. D. Warters and H. F. Rowe, Bell Telephone Labs., Inc., Holmdel, N.J.

II-10 "Pulse Responses of some T. E. M. Transmission Line Components" 4:50-5:05 P.M.
W. J. Getsinger, Stanford Research Institute, Menlo Park, Calif.

SESSION III CAMBRIDGE ELECTRON ACCELERATOR
Monday, June 1, 1959 at 8:00 P.M.

III-1 Invited Paper "Radio Frequency Systems of the Cambridge Electron Accelerato 8:00-8:30 P.M.
K. W. Robinson, C.E.A., Cambridge, Mass.

III-2 "Model Studies of a Strongly Coupled Synchrotron R-F System" 8:30-9:00 P.M.
J. Deklava, A. F. Barrington and J. R. Rees, C.E.A., Cambridge, Mass.

III-3 Visit to the Cambridge Electron Accelerator 9:00-10:00 P.M.

SESSION IV MASER TECHNIQUES Tuesday, June 2, 1959 at 8:45 A.M.
Chairman: M. Weiss, Bell Telephone Laboratories, Holmdel, N.J.

IV-1 Invited Paper "Physical Principles of Solid State Masers" 8:45-9:15 A.M.
N. Bloombergen, Harvard University, Cambridge, Mass.

IV-2 "Relaxation Effects in Maser Materials" 9:15-9:30 A.M.
S. Shapiro, Harvard University, Cambridge, Mass.

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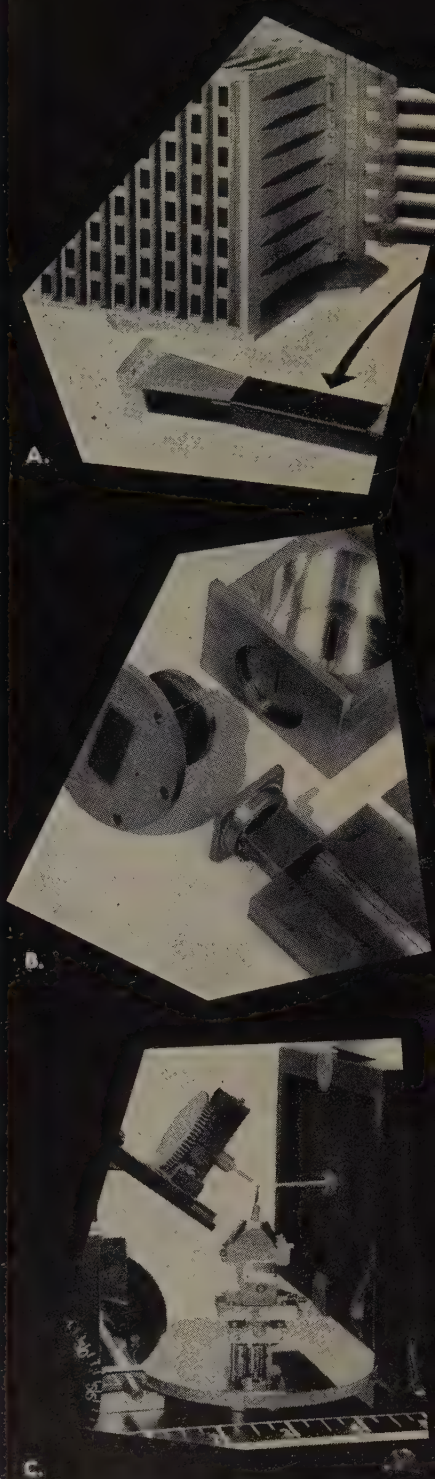

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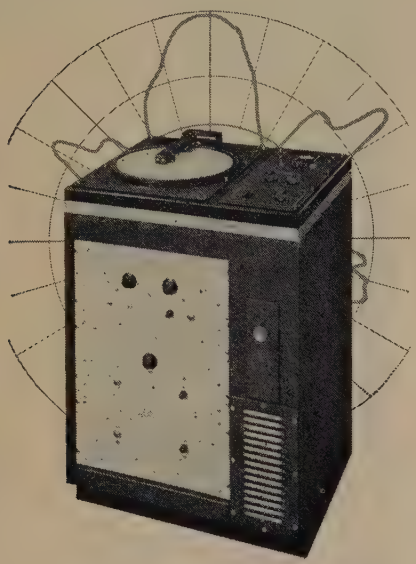

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PGMTT Symposium Program (Continued)

IV-3 "An L-Band Y-Junction Circulator" 9:30-9:45 A.M
L. Davis, Jr., U. Milano and J. Saunders, Raytheon Mfg. Co., Waltham, Mass.
IV-4 "Low-Temperature Germanium Microwave Switch" 9:45-10:00 A.M
R. H. Kingsten and S. H. Autler, MIT Lincoln Laboratory, Lexington, Mass.

INTERMISSION 10:00-10:20 A.M

IV-5 Invited Paper "Quantum Mechanical Amplifiers, Present Performance Statue" 10:20-10:50 A.M
M. W. P. Strandberg, Mass. Institute of Technology, Cambridge, Mass.
IV-6 "The Design of Large Gain Bandwidth Produce Masers" 10:50-11:05 A.M
W. From, Ewen-Knight Corp., Needham, Mass.
IV-7 "Packaged Tunable L-Band Maser System" 11:05-11:20 A.M
F. R. Arams and S. Okwit, Airborne Instruments Laboratory, Mineola, N.Y.

SESSION V MICROWAVES II Tuesday, June 2, 1959 at 2:00 P.M
Chairman: Eugene Fubini, Airborne Instruments Laboratory, Mineola, N.Y.
V-1 Invited Paper "Survey of Noise Figure Problems" 2:00-2:30 P.M
P. Strum, Granger Electronics, Palo Alto, Calif.
V-2 "Analysis of Cascaded Microwave Network by Means of Signal Flow Graphs" 2:30-2:45 P.M
K. Hunton, Hewlett-Packard Co., Palo Alto, Calif.
V-3 "Measurement of Bandwidth of Microwave Resonator by Phase Shift of Signal Modulation" 2:45-3:00 P.M
D. S. Lerner and H. A. Wheeler, Wheeler Laboratories, Inc., Great Neck, N.Y.
V-4 "A Double-Sweep Comparator for Microwave Ferrite Device Measurements" 3:00-3:15 P.M
J. A. Weiss and R. W. Judkins, Bell Telephone Labs., Inc., Murray Hill, N.J.

INTERMISSION 3:15-3:35 P.M

V-5 "Comparison of Deviations from Square Law for R.F. Crystal Diodes and Barretters" 3:35-3:50 P.M
G. U. Serger and B. O. Weinschel, Weinschel Eng. Co., Inc., Kensington, Md.
V-6 "The Accumulation of Small Errors in Extended Periodic Structures" 3:50-4:05 P.M
M. C. Pease, Sylvania Electric Products, Inc., Mountain View, Calif.
V-7 "Theory of the Germanium Diode Microwave Switch" 4:05-4:20 P.M
R. V. Garver, J. A. Resado and E. F. Turner, Diamond Ordinance Fuze Labs, Washington 25, D.C.
V-8 "Single-Pole Double-Throw Wideband Microwave Switch" 4:20-4:35 P.M
M. Bloom, Sylvania Electronic Systems, Waltham, Mass.
V-9 "Diodes in Multipole Switches and Time Varying Dielectrics" 4:35-4:50 P.M
J. Galejs, Sylvania Electronic Systems, Waltham, Mass.

SESSION VI FERRITES Wednesday, June 3, 1959 at 8:45 A.M
Chairman: E. Strumwasser, Hughes Aircraft Company, Culver City, Calif.
VI-1 Invited Paper "Recent Advances in Materials for Microwave Ferrite Devices" 8:45-9:15 A.M
V. Jones, Harvard University, Cambridge, Mass.
VI-2 "L Band Ferromagnetic Resonance Experiments at High Peak Power Levels" 9:15-9:30 A.M
J. H. Saunders, F. Schlemann and M. H. Sirvets, Raytheon Mfg. Co., Waltham, Mass.
VI-3 "High Power Ferromagnetic Resonance at X-Band in Polycrystalline Garnets" 9:30-9:45 A.M
J. J. Green, Gordon McKay Laboratory, Harvard University and E. Schlomann, Raytheon Mfg. Co., Waltham, Mass.
VI-4 "Use of Demagnetizing Fields to Minimize Temperature Effects in Ferrite Devices" 9:45-10:00 A.M
W. H. VonAulock, Bell Telephone Laboratories, Inc., Whippany, N.J.

INTERMISSION 10:00-10:20 A.M

VI-5 Invited Paper "Some New Ferrite Design Forms" 10:20-10:50 A.M
Harold Seidel, Bell Telephone Laboratories, Inc., Murray Hill, N.J.
VI-6 "The Design and Operations of Two Types of Medium Power Microwave Ferrimagnetic Limiters" 10:50-11:05 A.M
E. N. Skomal and M. A. Medina, Sylvania Elec. Prod. Inc., Mountain View, Calif.
VI-7 "Ferrite Multi-Mode High Power Signal Suppressor" 11:05-11:20 A.M
W. C. Heithaus, S. C. Sloan, B. J. Duncan and L. Swern, Sperry Microwave Electronics Company, Clearwater, Florida
VI-8 "A New Approach to the Design of Low Frequency Ferrite Phase Shifters" 11:20-11:35 A.M
R. L. Fogel, Hughes Aircraft Company, Culver City, California
VI-9 "Broad Band Ridge Waveguide Ferrite Devices" 11:35-11:50 A.M
F. S. Grimes, Jr., D. D. Bartholomew, D. C. Scott, and S. C. Sloan, Sperry Microwave Electronics Co., Clearwater, Florida

SESSION VII VARIABLE REACTANCE DEVICES
Wednesday, June 3, 1959 at 2:00 P.M
Chairman: H. Haus, Massachusetts Institute of Technology, Cambridge, Mass.
VII-1 Invited Paper "Progress Report on Variable Capacitance Diodes" 2:00-2:30 P.M
A. Uhlir, Microwave Associates, Burlington, Mass.

PGMTT Symposium Program (Continued)

VII-2 "RF Logic Circuits Using Subharmonic Oscillators" 2:30-2:45 P.M.
F. Sterzer, Radio Corporation of America, Princeton, N.J.

VII-3 "A Variable Reactance Diode Phase Shifter" 2:45-3:00 P.M.
F. Stern, General Electric Company, Syracuse, N.Y.

VII-4 "Theory of Filter-Type Parametric Amplifiers" 3:00-3:15 P.M.
P. Parzen, Radio Corporation of America, New York, N.Y.

INTERMISSION 3:15-3:35 P.M.

VII-5 Invited Paper "Parametric Amplifiers: State of the Art" 3:35-4:05 P.M.
R. S. Englebrecht, Bell Telephone Laboratories, Inc., Whippany, New Jersey

VII-6 "Performance of Low-Noise Tunable-Cavity and Traveling-Wave Parametric Amplifiers" 4:05-4:20 P.M.
E. M. T. Jones, R. C. Honey and J. S. Honda, Stanford Research Institute, Stanford, California.

VII-7 "Design and Field Test of Two Different Types of Reactance Amplifiers" 4:20-4:35 P.M.
James Poppe and H. J. Peppiatt, General Electric Company, Syracuse, N.Y.

VII-8 "Some Considerations of Four-Frequency Parametric Circuits" 4:35-4:50 P.M.
David Adams, The University of Michigan Research Institute, Ann Arbor, Mich

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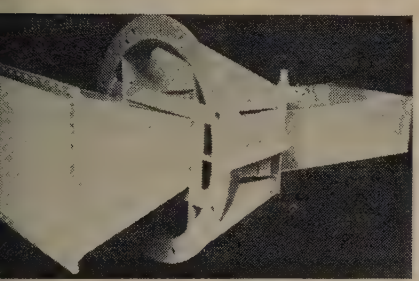

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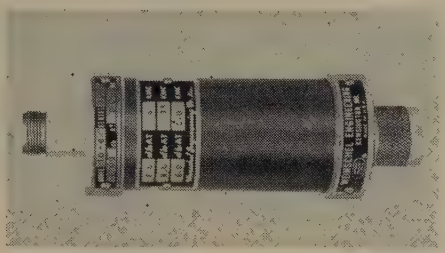

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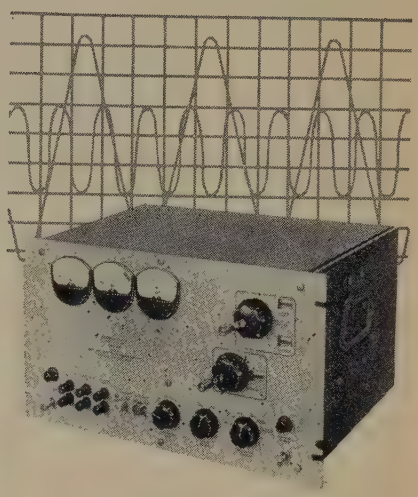

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CIRCLE READER SERVICE CARD 21

I-T-E CIRCUIT BREAKER COMPANY
SPECIAL PRODUCTS DIVISION

Ashton T. Scott, Vice-President and Manager, I-T-E Special Products Division.

BOX SCORE

NAME: I-T-E Circuit Breaker Co., Special Products Division.

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PRODUCTS: Fabrication of antennas and communications equipment; development and manufacture of complete antenna systems; UHF waveguide, and large waveguide test equipment; scatter communication antenna systems.

HIGHLIGHTS: Special Products Division, Engineering Products Section an organization exclusively devoted to design, development, production and testing of antenna systems; prime contractor for ACE HIGH forward scatter communications system for NATO nations.

Parent Company

When, about the turn of the century, a gay blade o the time popped a Sen-Sen into his mouth, secured hi Sunday straw to his lapel with the string provided, an took off to spend a jolly hour on the trolley, it is a fai bet that somewhere in the control circuit of his trolle line was a product of a young company, lately forme to serve the needs of the new and expanding electrica transportation system. This company was known as th Cutter Electrical Manufacturing Company, and was th direct antecedent of the firm that is known today as th I-T-E Circuit Breaker Company.

The Cutter firm was founded in 1887 for the purpos of producing circuit breakers for traction companie Electrical traction, at that time utterly new, was t flourish in the next few decades and cover the countr with a web of urban and interurban lines; but at th time of the company's founding, it required considerabl foresight and imagination to stake a future in such a enterprise. The young company, then, struck a keynot which has remained as a guide to this day — I-T-E ha demonstrated that it is ever looking to enter new field and to widen its areas of interest.

The vigorous evolution of I-T-E since those early day is ample confirmation of this astute managerial polic I-T-E management, coming, in 1900, under the influ

nce of the Scott family in the person of W. M. Scott, r., and continuing to this day under his sons, has teered a successful course, though it has not at all imes been without difficulty. In the depression ridden Thirties, for example, the new equipment account was upported solely by the sale of scrap copper! In spite f these difficulties, the Company consistently earned profit.

A word here about the name "I-T-E" might be appropriate. About the year 1904, in its sixteenth year, he Cutter Electrical & Manufacturing Company introuced a circuit breaker with an Inverse Time Element ripping device. This was a breaker that opened in horter intervals as the overcurrent increased. Thereafter, Cutter Company breakers were identified with a ircular I-T-E trademark, and within a few years engieers in the electrical industry were referring to the Cutter Company as the "I-T-E Circuit Breaker Company." In 1928 the name was formally adopted, identifying the company with the product it had introduced.

Today, I-T-E operates on an international scale. The ompany is made up of eleven operating divisions and our subsidiary companies. Sales in 1958 totalled well ver $100 millions. Common stock of the company is isted on the New York Stock Exchange, and is currently elling for about $40 a share. Company products and acilities, management says, enables the I-T-E Circuit reaker Company to provide a unified, co-ordinated ervice throughout the entire electric power distribuon system of industrial plants.

I-T-E organized the operating divisions and acquired he subsidiary companies in order to keep ahead of the idening needs of the electrical industry. In 1946, in rder to gain a larger foothold in defense business and btain a better area for research into materials and rocesses involved in this field, I-T-E organized a divion to specialize in the fabrication of radar antennas nd jet engine components, and named this new operaon the Special Products Division.

Special Products Division — Engineering Products Section

This division began in 1946 with facilities "borrowed" from other divisions of the parent company, and with a working force of 100 people.

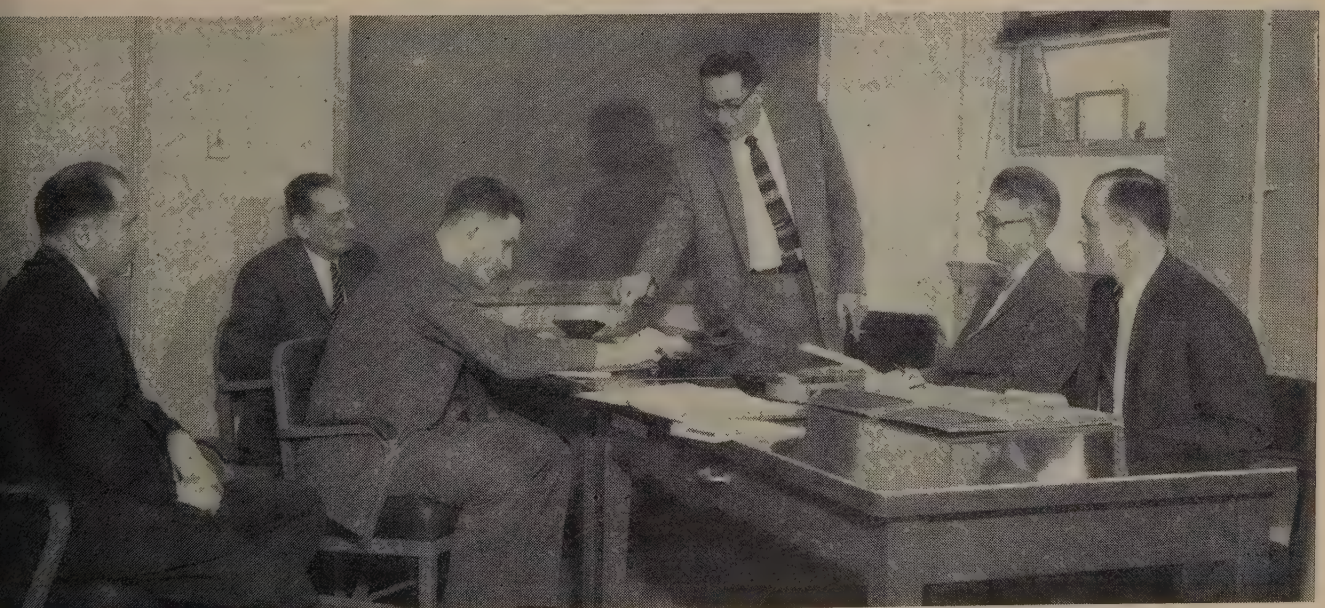
In 1954, activities of the sections of this division had increased enough to warrant a reorganization into two separate sections, for the purpose of separating the antenna and the jet engine activities. The Engineering Products Section was thus formed to engage in the design, development and production of antenna systems and related components. The jet engine facility is known as the Jet Components Section. These two sections operate as divisions of the company; about the only things they have in common are the sharing of some facilities, and the fact that they are headed up by Ashton T. Scott, Vice-President and Manager, Special Products Division.

Engineering Products Section — Management

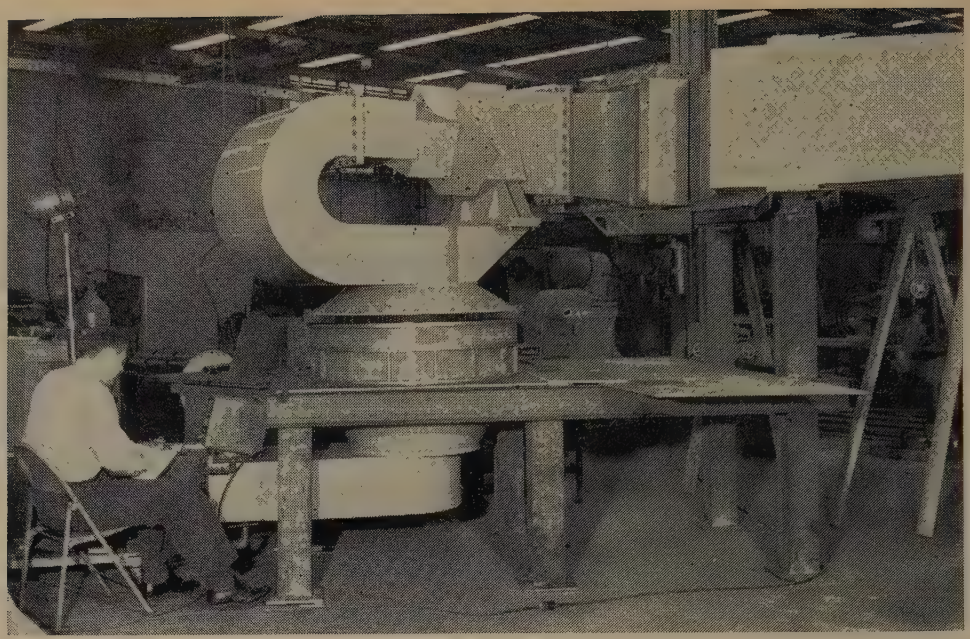
It had become apparent in 1946 that radar and microwave communications were becoming a substantial industry. Ashton Scott gathered a few key personnel, and embarked on what was, for I-T-E, a new field of endeavor — the production of radar antennas and communications antenna systems.

Ashton T. Scott is a brother of W. Maxwell Scott, Jr., who is President of I-T-E. Both are sons of W. M. Scott, Sr., who was President of the firm from 1900 until the time that his son took over that office. Ashton Scott is a graduate chemical engineer, Yale University, a registered professional engineer, and a member of Sigma Xi. He served with the Bureau of Ships as a Commander during World War II; before the war he had been Director of Research for Sharples Corp. He has been Manager of the Special Products Division since his return from active service in 1946.

As manager of the new Section, Scott selected Frank J. Gardiner. Frank is a mechanical engineer who studied his profession in Europe and at MIT. Much of his early experience was in the fields of aerodynamics



formal management conference; left to right, George Raynes, production manager; Harry Horwitz, staff assistant; Frank Gardiner, neral manager; Jerome Corwin, chief mechanical engineer; David Bowman, chief r-f engineer; Paul Garrison, sales manager.



Testing high power rotary joint and step-twist assembly.

and thermodynamics. Applying himself to the problems of microwave technology, he is today recognized as an authority in the field of mechanical and electrical antenna design. Before coming to I-T-E, Gardiner served with the U.S. Navy, and was employed by the Chrysler Corp.

Mechanical servo and project engineering is headed by Jerome Corwin, who has had wide experience in radar antenna design. Jerry is a registered professional engineer and a member of Sigma Xi. He brought with him to I-T-E 15 years' experience in radar and communication antenna system design and development at Evans Signal Laboratory.

David Bowman, leader of the R-F Engineering Department, has an advanced degree in Electrical Engineering, and has buttressed his training with more than 15 years' experience in R-F testing and design with Hazeltine, Airborne Instruments Lab., and as chief engineer at Development Engineering Corp.

The important area of sales is under the direction of Paul A. Garrison, a graduate of the U.S. Naval Academy and of Harvard Business School. Paul has rounded out the sales section with six sales representatives who cover government and commercial accounts for the purpose of sales and contract administration on major antenna projects.

Production Manager is George Raynes, a Mechanical Engineering graduate of Drexel University, who for many years was Superintendent of Quality Control in the Special Products Division. He leads an experienced group of production engineers and has an impressive production facility which has evolved many types of antennas, and in large quantities.

Completing the Engineering Products Section management team is Harry Horwitz, who is currently serving as staff assistant to Frank Gardiner, and is responsible for budgeting and scheduling. Harry has been with the Special Products Division since its beginning in 1946, and had served in Engineering Administration.

Plant Facilities

From its originally borrowed working area, Spec Products Division now occupies five single story buil ings which provide more than 300,000 square feet manufacturing area. A building program is now un way which will add 50,000 square feet to the Enginee ing Products Section to aid in handling the increas work load. This project is expected to be finished August 1, 1959. The employment rolls of the divisi currently list over 1000 people.

The Section cites among its ample laboratory and t facilities a reaction-type vibration stand which is capal of handling antennas heavier than 5000 pounds. large environmental chamber was installed within t last year. A number of fully-instrumented pattern t ranges, up to 8800 feet, are available.

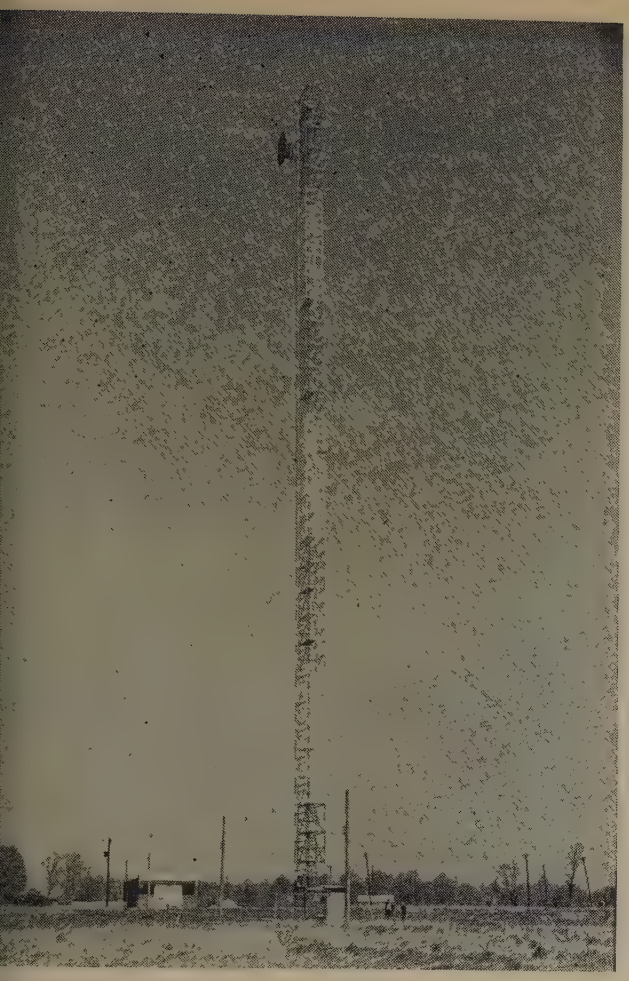
Product

Prior to 1954, the major efforts of the Special Pro ucts Division were in the fabrication of antennas a communications equipment. Since that time, howev the company says that increasing emphasis has be placed on the development of antenna systems as well on their fabrication, and very substantial progress claimed in this important area. Management offic point out: "Our aim has been to develop facilities a personnel which will enable us to become a compl source for all types of antenna systems."

Over the past few years, I-T-E has been particula active in the design and manufacture of radar syste for the Bureau of Ships. Paul Garrison says: "We a at this time, a major supplier of antenna systems to t Bureau of Ships."

The preponderance of the company's work has be in the search radar field. Projects have ranged fr very small commercial marine scanners to giant 60-f antennas used in ground-based early-warning appli tions.

Currently, the Division has over 25 different types



Assembling elements for test on rotator

Tower on I-T-E pattern test range.

tenna systems and antennas in the design, develop-
ent or manufacturing stages.

In 1956 a line of UHF waveguide test equipment was
troduced, and the company says that it was one of the
l pioneers in the large waveguide field. Special em-
asis has been placed on the development of new and
ficult UHF waveguide components.

Garrison adds: "Although our activities and interest
ver the entire antenna field, we have tended to spe-
lize in, and have gained most of our experience
ere large and precise ground-based antenna systems
required."

To emphasize this view, the company points to its
owing activity in fixed scatter communications an-
na systems. Currently, the Division is working on
ACE HIGH project under contract from SHAPE.
is involves the design, manufacture, installation and
d service of more than 150 30- and 60-foot antennas.
e company has stated its intention to increase its ac-
ties in this area in the future.

Fiscal

The Engineering Products Section is currently ship ping at the rate of about $8 millions per year. Officers of the Section estimate sales of $10 millions in 1960, and by 1961, $15 millions. They foresee an increasing non-military market, and are devoting considerable attention to this sphere of microwave activity.

Future

In this necessarily brief profile we have traced I-T-E's progress from the high button shoe era to the present space age; the company record has been one of judicious prognostication, followed by appropriate action. We, then, whose interests are interwoven with the future of the microwave industry, can draw real comfort from this statement by the head of I-T-E's Special Products Division: "Engineering Products Section is committed to a program of further growth. As our growth in the past has been a result of engineering emphasis, our future growth will be tied to the strengthening and expansion of our engineering departments."

"Some Dish!"

Psychologically, most men conjure great visions of soft and pleasant femininity when they see these words.

Practically, if your dish at the moment is along paraboloidal lines, perhaps you could use our help in providing special fabrications in plastics.

Models are our dish, starting with prototype which then leads to full production on a precision basis.

• Fact File describes our facilities

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NEW PRODUCT RELEASES

RAYTHEON OFFERS NEW BACKWARD WAVE OSCILLATOR

The Raytheon QK625 is a voltage tunable wide band (2500-3300 mcs.) C.W. backward wave oscillator providing a minimum power output of 180 watts and a nominal power output of 250-350 watts over the band. Tuning sensitivity is approximately 0.35 mcs. per volt. The tube is designed with an integral permanent magnet and weighs approximat twenty-five (25) pounds. The output is standard 7/8" coaxial.

The QK625 is liquid cooled a may be mounted in any position. is excellent for countermeasures a FM C.W. operation. It can be a plitude and/or frequency modulat at rates up to and exceeding 10 m

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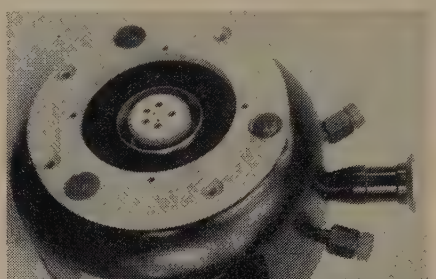

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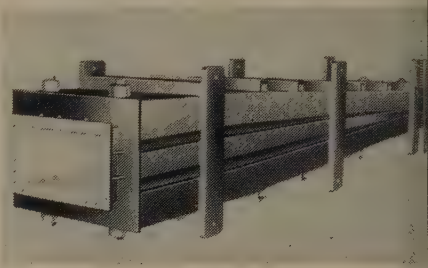
LARGE WAVEGUIDE DUMM LOADS BY BOGART

A series of dry dummy loads f large waveguide sizes has been cently introduced by the Bogart Ma ufacturing Corporation, Brookly New York.



The WR-4073 series has been d signed for extremely high power a plications and incorporates auxilia

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quid cooling. A brief description three models of the series:

(1) Model WR-4073-18 for WR-300 waveguide. This load can absorb an average power of 350 KW with a peak power of 11 MW.

(2) Model WR-4073-21 for WR-100 waveguide. This load can absorb an average power of 600 KW with a peak power of 15 MW

(3) Model WR-4073-15 for WR-500 waveguide. This load can absorb an average power of 250 KW with a peak power of 7.5 MW.

All units make use of VHP Lossy Material which is approved by all Armed Forces Agencies for humidity, shock, and vibration.

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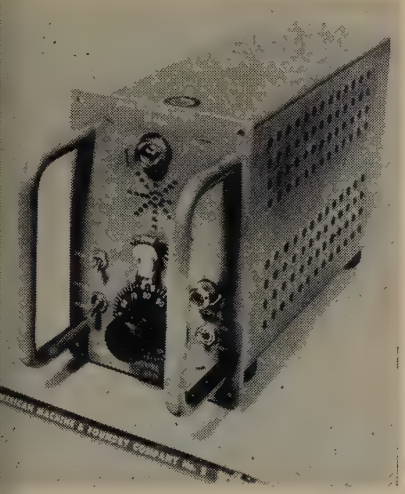
AMF UNIVERSAL TR TUBE LEAKAGE MONITOR

A simple effective instrument for continuously monitoring a radar's TR tube has been developed by the Greenwich Engineering Laboratories, American Machine & Foundry Company, Greenwich, Connecticut.



Operation with an appropriate directional coupler and diode detector allows the leakage monitor to be readily adapted to any radar power, frequency, or duty cycle.

Designed to detect TR tube malfunction, the AMF transistorized monitor signals an audible or visible alarm under conditions of excessive TR power leakage.

The new unit measures 3 by 4½ by 7 inches and weighs 31 lbs.—6 oz. Operating from a 115 volt 50/60 cycle A-C supply, its power consumption is only 4 watts.

CIRCLE READER SERVICE CARD 105

(More NEW PRODUCTS *on page 51*)

TO SERVE YOUR EXACT NEED...

HIGH POWER
LOW POWER
BROAD BAND
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HIGH ISOLATION
SMALL SIZE
LIGHTWEIGHT

Added to the broad range of current Ferrite Isolators is an intensive program to conduct research and development in advanced ferrite devices for the frequency bands proposed for space navigation and communication.

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W-177-1K-1	9.5 KMC ±100 MC	25 DB Min.	.7 DB MAX	1.15 MAX
W-277-3A-3	5.2-5.9 KMC	17 DB Min.	1.0 DB MAX	1.15 MAX
W-859-11A-1	930 ±60 MC	25 DB Min.	2.0 DB MAX	1.25 MAX
W-668-1A-2	8.5 –9.6 KMC	10 DB Min.	0.4 DB MAX	1.10 MAX

Engineers: Kearfott offers challenging opportunities in advanced component and system developments.

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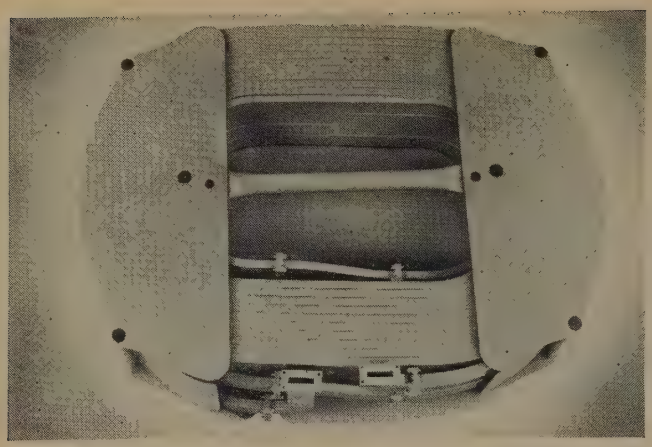

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SINGLE COILS UP TO 78 FEET IN LENGTH
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Turbo "packaged" delay lines are readily contained in standard test racks. Typical 1000 ft. assembly is 2 ft. dia. x 15″ high. Complete test assemblies, and slotted waveguide antenna assemblies, built to specification. Bulletin on request.

TURBO DELAY LINES

TURBO MACHINE COMPANY, LANSDALE, PA.

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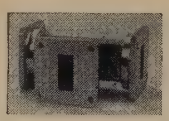
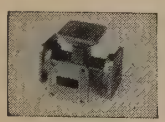
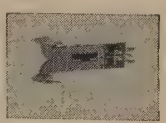




Standard Waveguide Components and Test Equipment



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This is an outstanding opportunity to become associated with one of the Nation's leading antenna groups. We are presently working on more than thirty different types of antennas, including antenna systems for airborne equipment for missiles and supersonic aircraft, as well as ground based and submarine antenna systems. Our modern and complete facilities include a wide variety of antenna test ranges.

Location: Melpar's ultra modern main Laboratory in Falls Church, Virginia, suburban to Washington, D. C.

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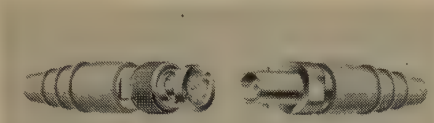
NEW PRODUCTS

NEW BNC CONNECTORS FROM AMPHENOL



A new line of BNC RF connectors that can be assembled in half the time required for ordinary connectors has been announced by the Amphenol Connector Division of Amphenol-Borg Electronics Corp. The new connectors, called "Quick-Crimp," are partially pre-assembled before shipment into only three basic parts (plus an optional boot) as compared to as many as ten parts in a standard BNC connector. The manufacturer states that because many critical assembly operations have been eliminated reliability is also increased in "Quick-Crimp" connectors.

The new line consists of 19 different connectors which mate with standard BNCs if desired.

CIRCLE READER SERVICE CARD 106

• • •

BULLETIN OFFERED BY ALITE

Publication of a new 16-page, fully illustrated bulletin describing Alite High Alumina Terminal Bushings and Ceramic-to-metal Seals is announced by the Alite Division, U.S. Stoneware Co. The new two-color Bulletin A-40 gives complete specifications on Alite's expanded line of over 100 standard sizes of high voltage terminals, feed-throughs and cable end seals. Each type of terminal is clearly illustrated with photo as well as dimensional drawing and specification chart.

Also shown are various types of special hermetic seals and terminals with helpful information on ordering special components for specific applications. Included within the pages of this bulletin are the latest specification charts giving performance data and complete details on Alite's mechanical strength, high temperature resistance and electrical properties.

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Investigate now! CBS-Hytron offers unusual and challenging opportunities in these positions. Exceptional starting salaries. Excellent opportunity for advancement with a group that believes in close liaison between management and engineering. At CBS-Hytron, you receive individual recognition.

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Microwave Physics Laboratory

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The position available is that of directing the activities of Sylvania's well-established, expanding Microwave Physics Laboratory in Palo Alto, California. This laboratory is engaged in fundamental and applied research in microwave physics. Theoretical and experimental investigations are conducted on gases and solid materials. The present staff totals 50 employees including 25 engineers and scientists.

The position requires strong technical background plus demonstrated managerial ability.

Inquiries should be addressed to
Dr. R. G. E. Hutter, Manager
Microwave Components Laboratories
Sylvania Electronic Systems
A Division of

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GENERAL TELEPHONE & ELECTRONICS
P.O. Box 188 • Mountain View, California

INDUSTRY NEWS

DR. A. H. RYAN NAMED MANAGER OF GENERAL ELECTRIC'S MICROWAVE LABORATORY

Dr. Alden H. Ryan has been named manager of General Electric's Microwave Laboratory at Palo Alto, Calif. He replaces J. W. Nelson, who recently was named manager of General Electric's X-Ray Department.

Dr. Ryan joined the Microwave Laboratory in 1956, and was manager of the microwave techniques subsection prior to being named general manager.

A graduate of Oberlin college, Dr. Ryan also has a Ph.D. degree in physics from Iowa State college, and is a senior member of the Institute of Radio Engineers.

NEW MICROWAVE COMPANY ORGANIZED

The officers and personnel of the Microwave Electronic Tube Company, METCO, INC., announce their entrance into the microwave electronic field as producers of high quality tubes and microwave devices for both government and commercial application.

The new firm is located at 76 Lafayette Street, Salem, Mass., where it occupies 31,000 square feet of production space. The plant was formerly used by CBS-Hytron for the manufacture of electron tubes.

President-Treasurer of METCO, INC. is Richard J. Broderick; Vice-President, Harold Heins. Other corporation officers will be named later from the nine other stockholders of the new organization.

Duplexer Device Development

SECTION HEAD

Top responsibility in spearheading expansion of development and product engineering program in microwave gas switching and duplexer device field.

The Operations: Expanding, fully integrated engineering and manufacturing organization with complete product line responsibility in magnetron, TR, ATR and glass type special purpose tubes.

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SPECIAL TUBE OPERATIONS

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RESEARCH ENGINEERS

Challenging assignments are presently available for Electronic Engineers at all levels of experience to work on interesting military and industrial projects in the following areas:

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Electronic Instrumentation

Electronic Components - Electronic Interference

Microwave and Propagation Studies

Members of our Electrical Engineering Research staff enjoy an exceptional opportunity for personal and professional growth through project assignments carried out in an atmosphere conducive to good research. In addition they receive competitive salaries and benefits which include a generous relocation allowance and up to four weeks paid vacation.

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of Illinois Institute of Technology

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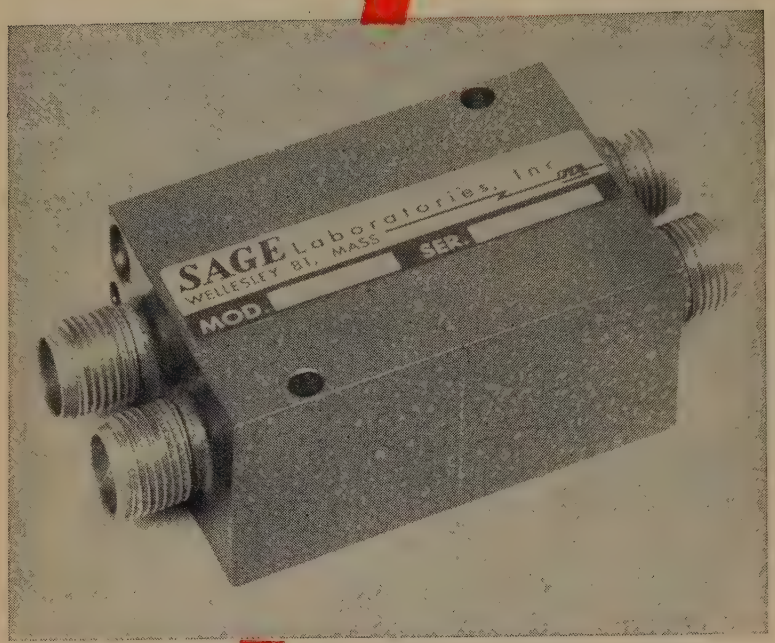

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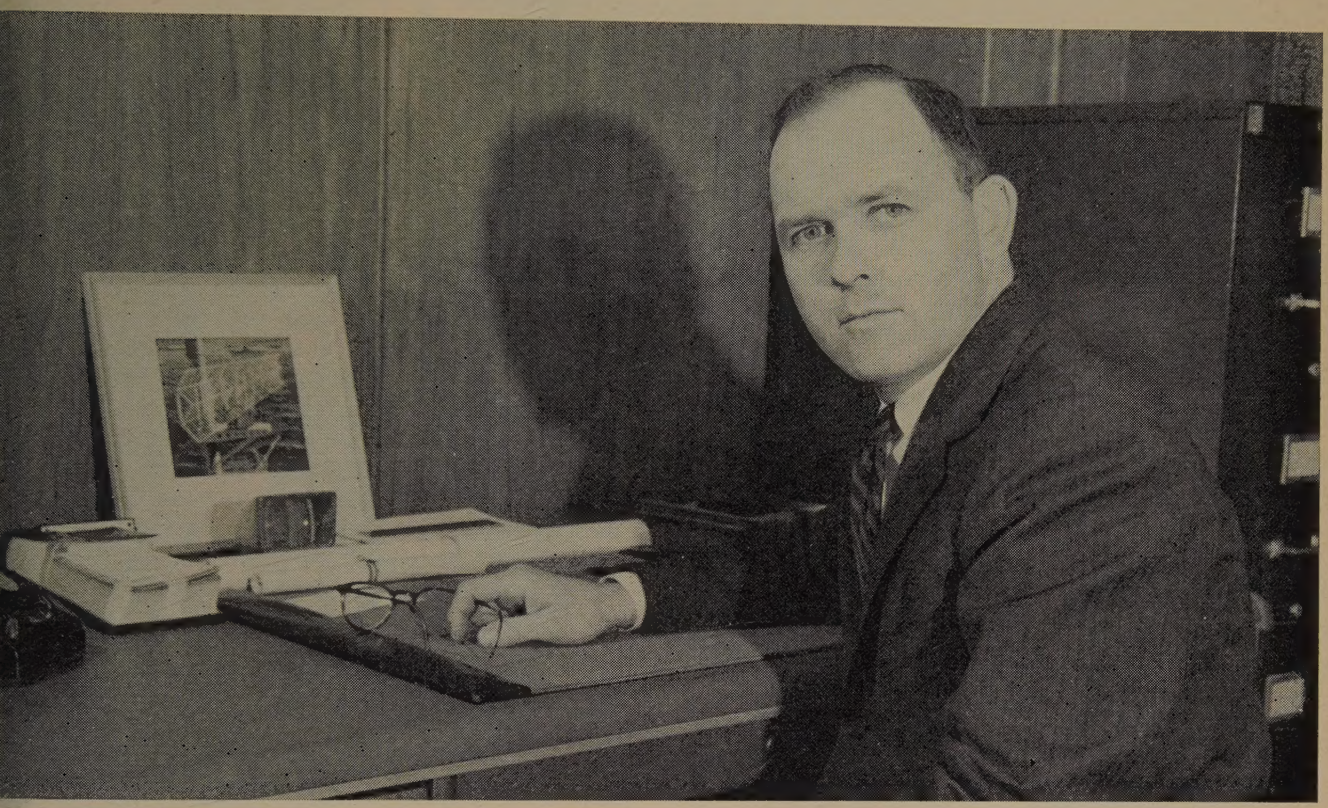
THE ANTENNA SLICE OF THE MICROWAVE BUSINESS . . . another view

PAUL A. GARRISON, Sales Mgr., I - T - E Special Products Div.



ul A. Garrison was born at McArthur, Ohio, in 1927. He is an honor graduate of the U.S. Naval Academy, where he received Bachelor's degree in electrical engineering. He also took special courses at Harvard University School of Business Administration. efore coming to I-T-E in 1954 as sales representative for the Special Products Division, he was assistant to the President, Design rvices Co. In 1958 Garrison was named sales manager of the I-T-E Engineering Products Section, where his responsibilities in- ude solicitation, negotiation and administration of contracts for antenna systems and components.

Paul's wife Jane was in the fashion merchandising business before her marriage; now three children and their home in osemont, Pa., occupy all of her attention.

Paul is a member of the Institute of Radio Engineers, and the American Society of Naval Engineers.

Charlie Creaser, in his editorial in the February issue *the microwave journal,* stated that "in some quarters the eling exists that the antenna slice of the microwave busi- ss is much too great." This is a point of view not neces- ily shared by all of us in the antenna business.

We suggest that they might like to join those of us who carving this big slice out of the system business. They ould realize that they would be joining an elite group very talented people who have taken monumental strides the last few years. There is plenty of room for them, ough, because there just does not seem to be enough ople with the "savvy" that it takes to bridge that gap tween a black box and free space. If you are a mechani- engineer with a good knowledge of electromagnetic ory, servos, and most of the practical aspects of physics, industry can use you.

Mr. Creaser has evaluated the "Large Antenna Market" having a gross dollar volume about 25 million for 1958-1960. The cost of the systems which will use these large antennas are estimated as running into the hundreds of millions. We would like to expand on this subject and submit that the antenna business will be at least $250,000,000 during the calendar year 1959. This at first seems to be a really staggering figure. On reflection, it becomes considerably more reasonable. Let me say that when I describe the antenna business, I am including complete antenna systems and a typical antenna system is made up of a reflector, mount, either fixed or movable, and a feed system with associated transmission lines, and also antenna speed control in some instances. Actually, I believe towers and radomes could also be included in this figure.

In arriving at this estimate, I am including antennas

used for communications, all types of radar including search, tracking, short and long range navigation, ground and airborne, missile tracking, telemetering and so forth.

In justifying this figure, consider that the antenna expenditure for electronics by the U.S. Government runs into billions of dollars. This expenditure is broken down into general classes of equipment such as radar, communications, computers and general data processing equipment, as well as test and control equipment. Certainly a great share of this is in the radar and communications field. A rule of thumb which is sometimes used states that the antenna system is 20% of a typical radar system. In communications systems, this percentage may be somewhat less. When we see published figures which indicate that the cost of the BMEWS system is around $800,000,000, the cost of the DEW LINE is generally known to be in the hundreds of millions of dollars, the fabulous estimates for the cost of the NIKE-ZEUS program, the cost of the electronic portions of various weapons systems, and that these systems that I have just mentioned are primarily radar and communications, then my figure of $250,000,000 per year for the antenna business actually seems rather conservative.

I have not even mentioned the less dramatic expenditures for radar and communications equipment on capital ships of the Navy, implementation of the airways modernization program, tactical radar and communications equipment for the U.S. Army and air defense electronic equipment for the Air Force.

There is much feeling to indicate that one of the reasons the antenna has not contributed more to overall systems performance in the past decade is that it has been largely ignored in the rush to perfect other portions of the system. Remember that the antenna gain is one of the few argumen s that enter the range formula to the one-half power; others are much weaker. This is certainly not consistent with the sometimes practice of considering the antenna to be of second order importance since it "doesn't really add anything."

In spite of the somewhat negative feelings that have been commented on above, there has certainly been real progress in antenna technology and practice in the postwar years. This growth, however, has tended to be in the degree of sophistication. It has tended to be evolutionary, rather than revolutionary. There have been relatively few inventions. In considering the types of devices that were being used for propagation in 1947, one is impressed with how familiar they are today and also how widespread their use is today. Maybe they are that good — and also — maybe the antenna field is being held back by the manner in which it has been necessary to operate.

The antenna business is to a large extent a subcontract business. This is true today and has always tended to be typical of this business. This means, to a considerable degree, that the antenna business is operating within a framework that has been described by those who are not a tenna people. And the antenna is a different breed of ca It does require that happy push-pull relationship betwe the mechanical and electrical. For maximum results, is necessary to have this push-pull relationship in the for ulating and specifying phases as well as the design a manufacturing. This would most certainly increase t contribution that the antenna could make to overall syste performance.

We have been generally pleased with results in t opportunities to do prime contract business. We belie that there have been real advantages which have accru to both parties when total freedom of communication w the specifying and using organization is allowed.

An example of this situation working to the advanta of everyone, is the relationship with the U.S. Navy Bure of Ships. As a result of first hand knowledge of t Bureau's operational requirements and fiscal vicissitud resulting from a long standing prime contract relatio ship, there is now existing a family of modular design a tennas, pedestals and rotary joints. Antenna systems bu up from these modules are making a major contribution improving the Navy's search radar systems at a relative small cost compared with new radar systems to give th increased performance. Other agencies are now taki advantage of these modules for improving system pe formance through antenna modification and replaceme

Another example of bringing radar systems up to da through antenna modifications is circular polarizati modification to the work horse terminal area radars the U.S. Air Force and Federal Aviation Agency. Aga major system performance improvement was attained antenna modification at a quite low cost compared to t cost of just one complete radar system.

The ACE HIGH program is a rather dramatic examp of a prime contract by an antenna outfit. We are in t process of supplying 152 antennas for the trans-Euro tropo-scatter system sponsored by the NATO countr and contracted for by SHAPE. In this instance, we a responsible for design, fabrication, testing and installati of the antennas, towers and foundations. Again we fe that the close coupling between the supplier and the us will result in better equipment faster and at less cost.

There is another area which should be exploited mo fully in increasing the return on the already large inve ment in the antenna business. Right now, when little mo than subtle improvements from program to program a expected, the antenna is usually the longest lead item the system. Why not spend more money on basic resear in antenna technology? Can we not in this manner e courage inventions and breakthroughs and thus build a store of kowledge and equipment for use as require

The antenna slice of the microwave business is gre It is great in terms of dollars and in terms of contributi We believe that the contribution could be even larger a the cost perhaps lower if more opportunities were sei upon to increase the stature of the antenna business.

EDITOR'S NOTE —

This "Microwave Business" feature was introduced in order to elicit points of view on microwave industry activities o business nature. Differences of opinion, which are keys to progress, appear — otherwise they might remain lost to us all. On t basis we say "Vive les differences!" and invite continued participation in this department.

Next month in this feature, Henry Frailey, Power Tube operations manager of Westinghouse Electric's Tube Division w write on "Protecting the Company's Investment in Creative Talent" and in July we expect a paper by Mr. Robert E. Lewis, Presid of Sylvania.

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BL-212	5.0	0.5	1200 V	0.8	100	5400–5900	50Ω SM Jack	8 oz.	
BL-223	5.0	0.7	1900 V	1.1	400	5400–5900	50Ω TNC Plug	10 oz.	
BL-226	5.0	0.5	1300 V	0.9	100	9100–9500	50Ω TNC Plug	8 oz.	
BL-227	5.0	0.5	1300 V	0.9	100	8700–9100	50Ω TNC Plug	8 oz.	
BL-228	5.0	0.5	1300 V	0.9	100	8300–8700	50Ω TNC Plug	8 oz.	
BL-230	5.0	0.7	2800 V	1.9	1000	5400–5900	50Ω TNC Plug	10 oz.	
BL-231	5.0	0.5	1450 V	1.0	200	5400–5900	50Ω SM Jack	8 oz.	
BL-233	5.0	0.7	2800 V	1.5	1000	9375	UG 40/U	11 oz.	
BL-242	5.0	0.7	1900 V	1.1	400	5400–5900	TNC or 50Ω N Plug	10 oz.	
BL-243	5.0	0.5	1450 V	1.0	200	5400–5900	50Ω SM Jack	8 oz.	
BL-245	5.0	0.7	2800 V	1.9	900	5400–5900	50Ω TNC Plug	10 oz.	
BL-247	5.0	0.5	1200 V	0.8	100	9100–9500	50Ω TNC Plug	8 oz.	
BL-250	5.0	0.5	1350 V	1.0	150	5400–5900	50Ω TNC Plug	8 oz.	
BL-M003	5.0	0.5	1300 V	0.9	100	9100–9500	50Ω TNC Plug	7 oz.	
BL-M004	5.0	0.5	1200 V	0.9	150	8900–9100	50Ω TNC Plug	8 oz.	
BL-M007	5.0	0.5	1300 V	0.9	100	9100–9500	50Ω TNC Plug	8 oz.	
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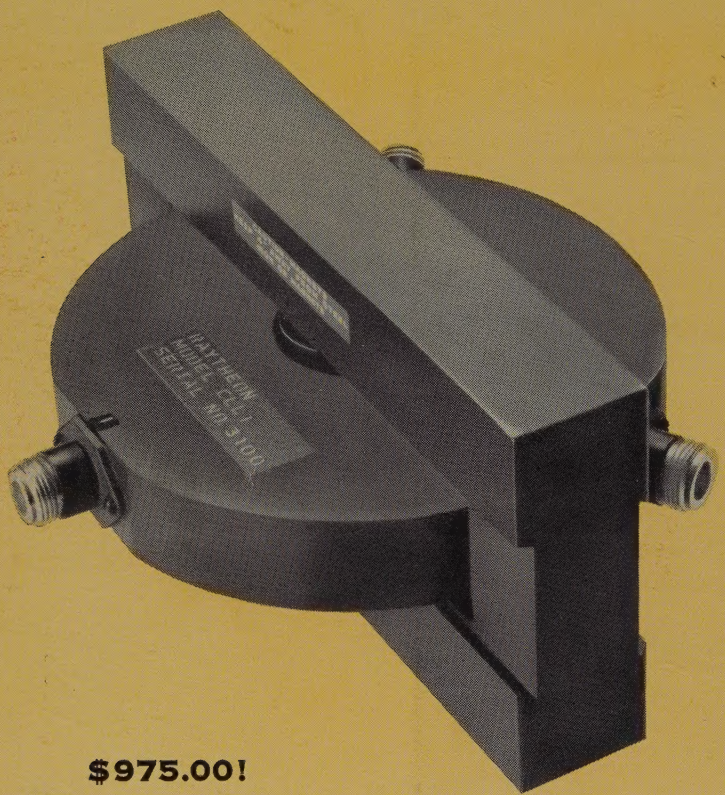

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Isolation		
Minimum	*20 db*	*20 db*
Maximum	*25 db*	*25 db*
Insertion loss		
Minimum	*0.3 db*	*0.3 db*
Maximum	*0.4 db*	*0.4 db*
Power Average	*5 watts*	*5 watts*
VSWR		
Minimum	*1.08*	*1.08*
Maximum	*1.25*	*1.25*
Weight (max.)	*9.0 lbs.*	*9.0 lbs.*
Max. dimension	*7½ in.*	*7½ in.*

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